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# Solitary trees in a warming and growing city: some outcomes from the GrüneLune project

GrüneLunge

www.projekt-gruenelunge.de

Karlsruhe palace, part of the city and palace garden

Photo: Sebastian Mang, KIT


**Somidh Saha**

**et. al.**

**somidh.saha@kit.edu**

**www.somidh.com**


**Presentation at the Congress „Stadt-Baum-Dach“ in Cologne on 11.09.2023**

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# GRÜNE STÄDTE EUROPA



KAMPAGNE FINANZIERT MIT FÖRDERMITTELN DER EUROPÄISCHEN UNION

DIE EUROPÄISCHE UNION UNTERSTÜTZT KAMPAGNEN, DIE DEN RESPEKT FÜR DIE UMWELT FÖRDERN

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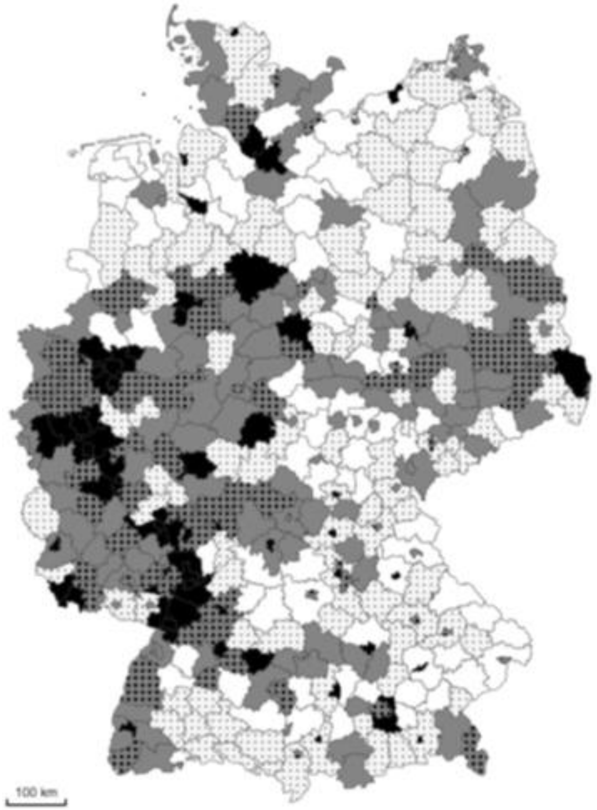
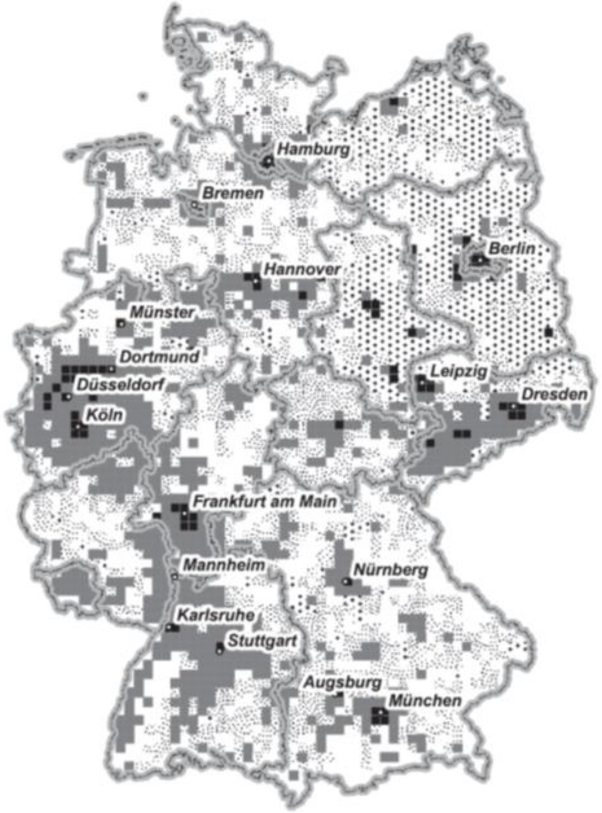
# Germany under Global Change




- **More land areas are becoming vulnerable to climate change impacts in Germany**
- **The watershed of the River Rhine is highly vulnerable**

- **At the same time urban sprawling is happpening in rapid pace**
- **This sprawling is more prominent in western Germany**

Rannow et al 2010 Sidentopf and Fina 2010

# Decline in urban and peri-urban forests

- High mortality of young solitary trees (ca. 30% per year in Karlsruhe)
- Loss of tree canopy cover
- Loss of large shade-bearing trees

**Key drivers**

- Drought and heatwaves
- Mangement challenges (keywords: irrigation, wrong species selection, low above and below ground growing space, tree care, staff shortage)
- Urbanization and densification
- Tree diseases

# Today I will only talk about:

1. Tree health condition (current/recent situation)
2. Tree growth and reaction to drought (look to the past before we think about the future: resilience, dendroecology, and stable isotope ecology)
3. Influence by trees on city temperature (microclimate modeling, remote sensing, and digital twin)
4. Tree as a habitat
5. Trade-offs between ecosystem services
6. Cultural ecosystem services from city trees

# Scope of this presentation

- Solitary city trees growing near parks and street (I refined this for this event ☺)
- Solitary trees are an essential part of the urban and peri-urban forests
- The FAO-Rome of the UN defines urban and peri-urban forests as: „Urban forests can be defined as networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas; they include, therefore, forests, **street trees**, **trees in parks and gardens**, and trees in derelict corners."
- Results presented here can be implementable or applicable in Karlsruhe city or city with a similar climate, geography, socio-economic situation

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# Case study GrüneLunge in Karlsruhe

- GrüneLunge 1.0: research and development phase (2018-2021)
- GrüneLunge 2.0: implementation phase (2022-2023)

## Academic partners

KIT

DWD
Deutscher Wetterdienst

FVA
Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg

ITAS
Institute for Technology Assessment and Systems Analysis

## Practice/community partners

Karlsruhe

***Gartenbauamt* and *Forstamt***

StadtRheinstetten

## Funding

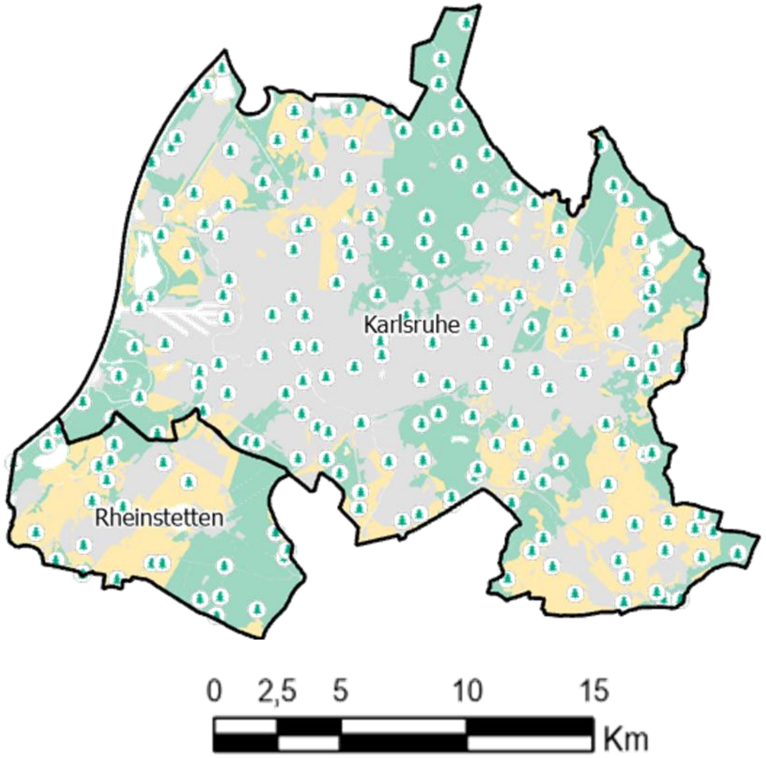
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

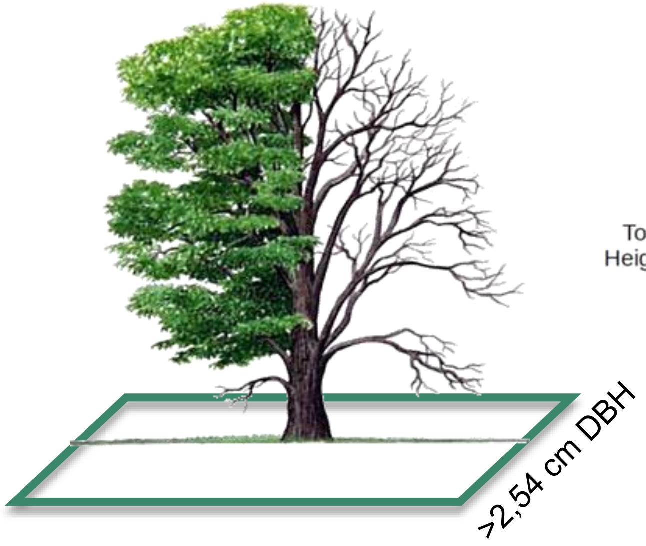
FONA
Forschung für Nachhaltigkeit

Zukunftsstadt

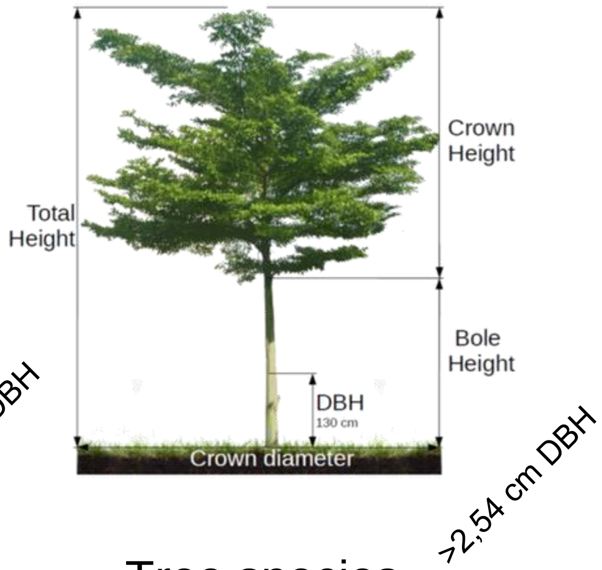
# Data

# Plot-based urban forest inventory (2019 & 2020)




Tree stress symptoms
Crown dieback
Missing crown
Defoliation
Discoloration



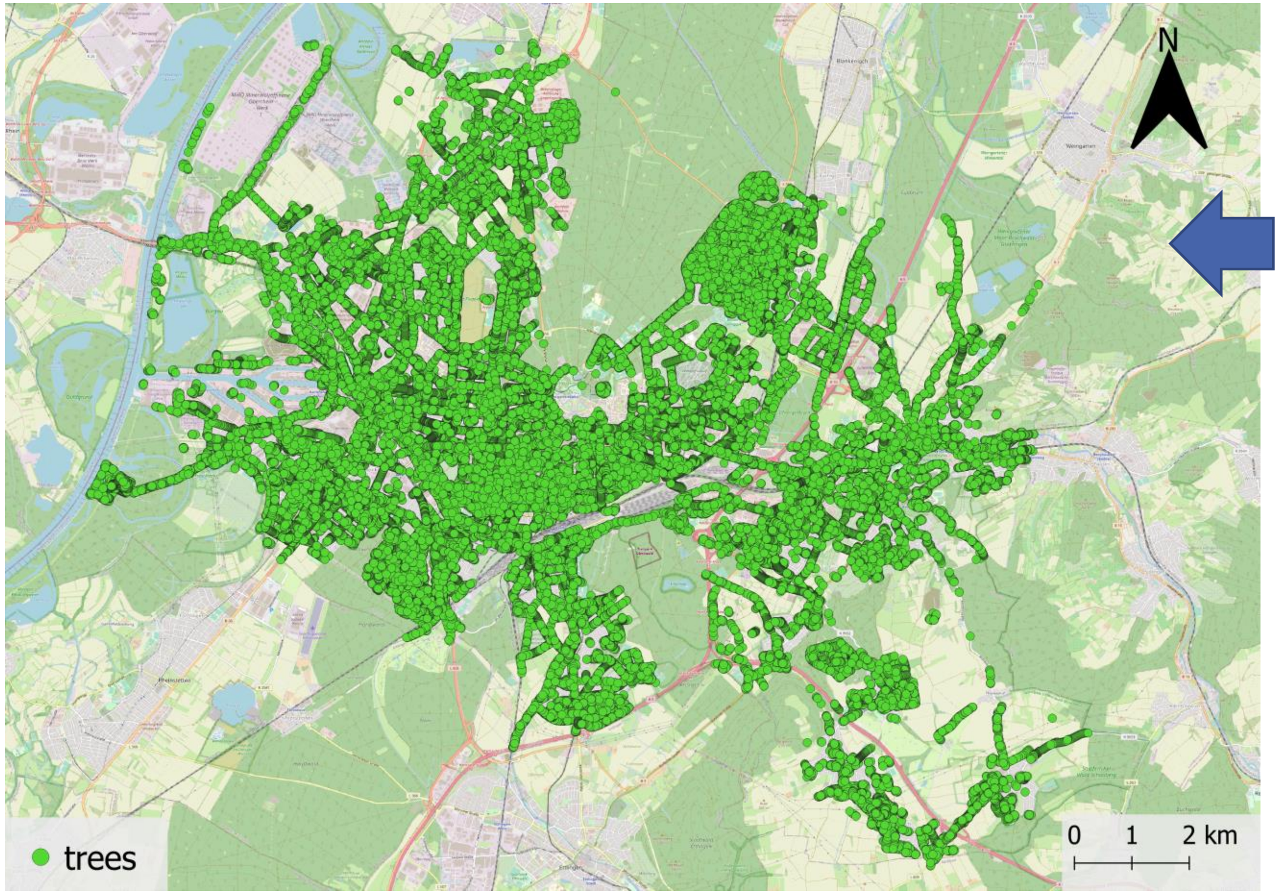

Tree species
Tree height
Tree diameter
Crown width

**201** Plots **2968** Trees **105** Species

(used i-Tree-Eco and i-Tree-Pest detection field guide)

Tree sketches: Root Problems (2021); NFA Forest Wiki (2020); Arboriculture International (2021) and TCV Scotland (2017)

# Tree cadaster and tree inspection data during safety evaluation




Map of **152,105 single standing trees**

Karlsruhe has in total, **394,700 single standing trees**

However, we used **79,573 single standing trees** for crown damage analysis

For those trees, inspections were carried out by City Tree Inspectors during "growing season" in 2019 and 2020

Data in Cadaster: crown damage class (FLL), species, diameter, and height, location, tree site (e.g. park, street etc.), data of tree inspection;

# Reaction to drought and pollution (dendroecology and stable isotope analysis)

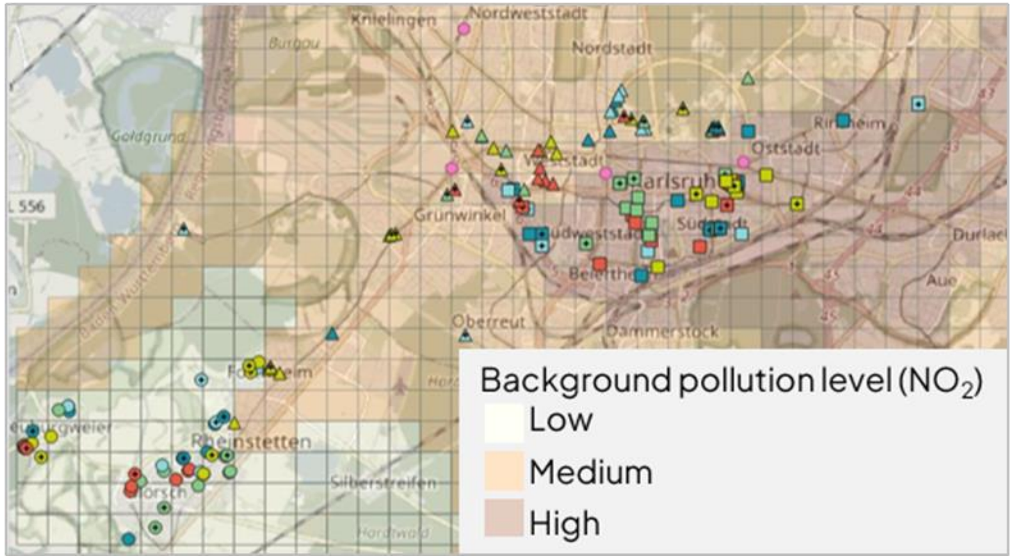
Norway maple
*Acer platanoides*

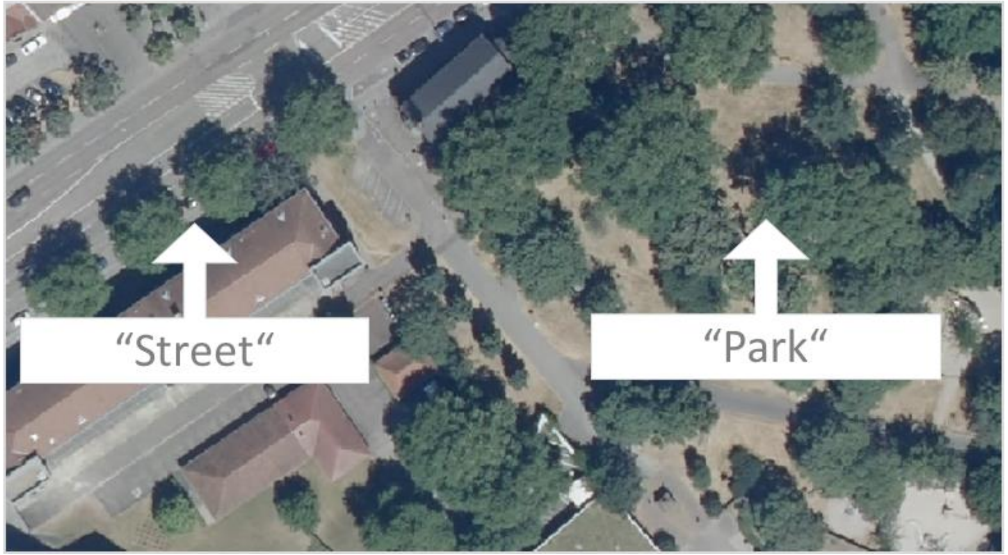
Hornbeam
*Carpinus betulus*

London plane
*Platanus × hispanica*

Common oak
*Quercus robur*

Small-leaved lime
*Tilia cordata*



# Dendroecology of exotic red oaks vs native pedunculate oaks and trunk internal damage (sonic tomography)

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Tree ring research and sonic impulse tomography were used in this study in addition to standard dendrometric assessment.



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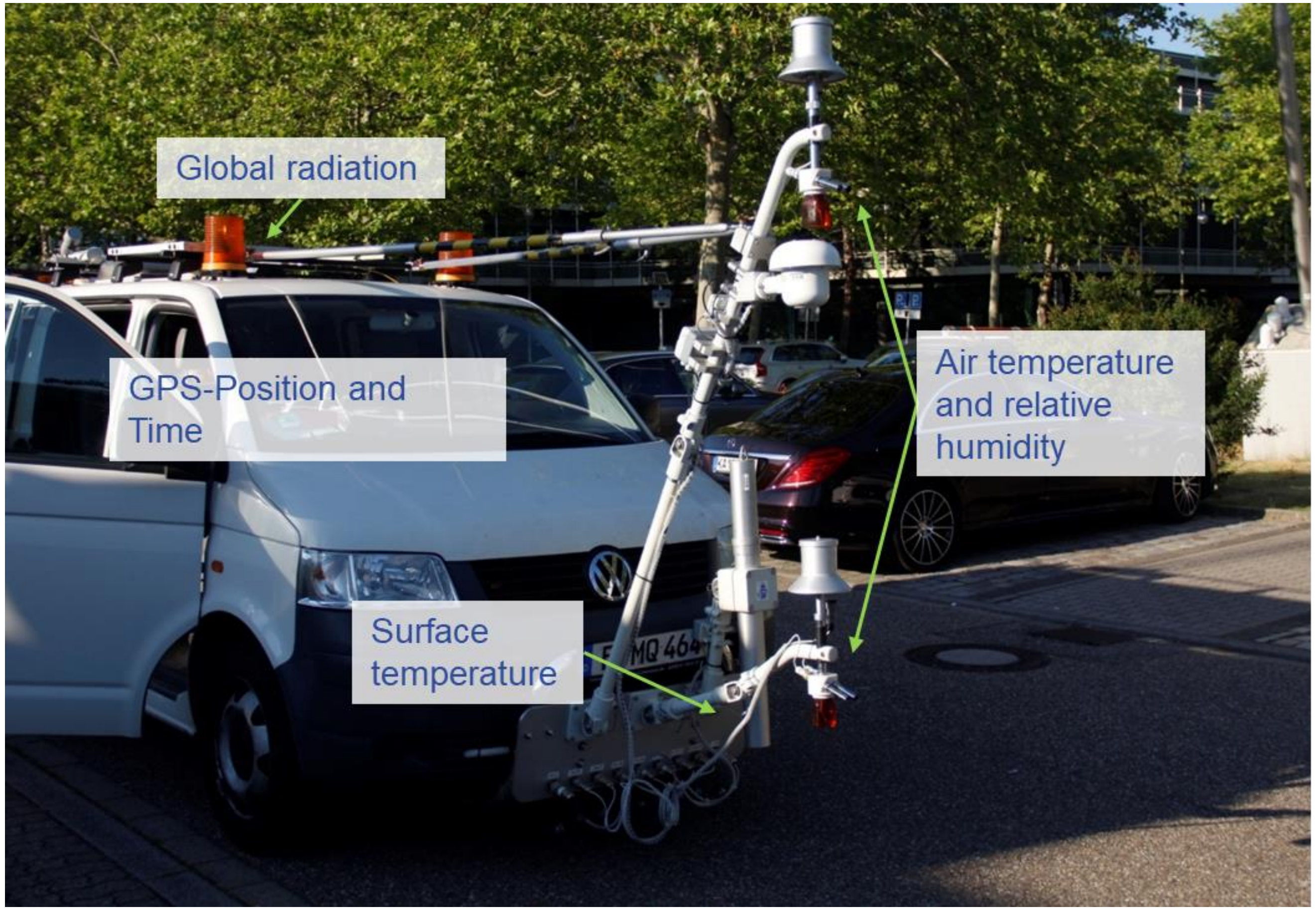
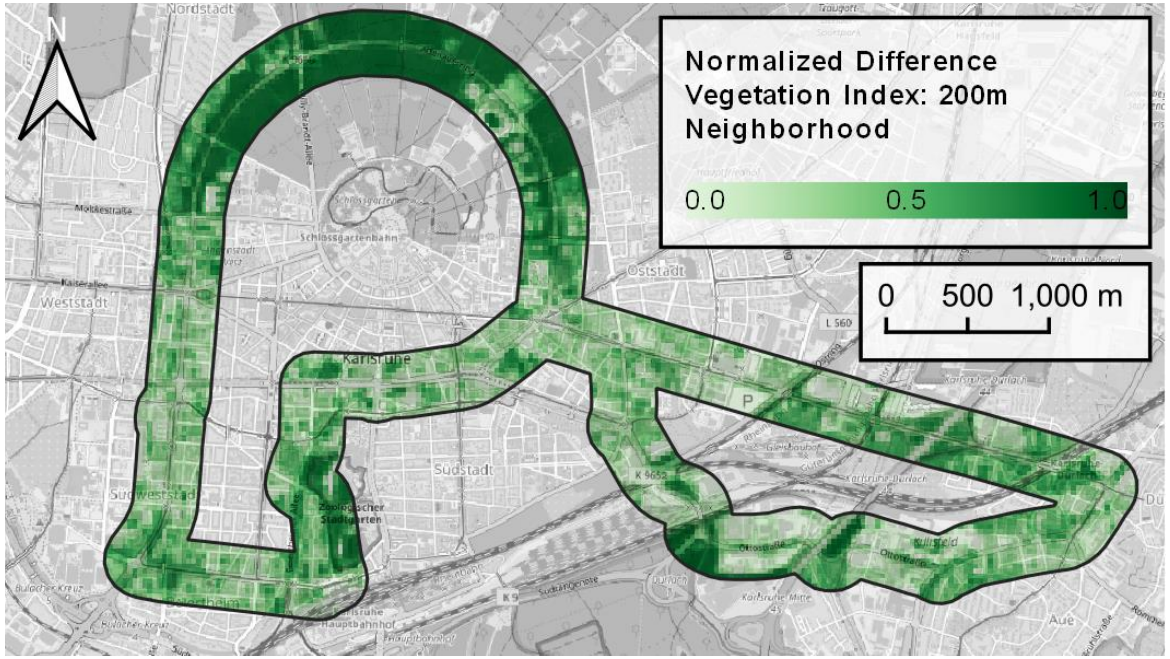
# Urban Micro Climate and Linking it to Urban Morphology



# Merging LiDAR-based digital twin, street tree composition, and microclimate along urban to peri-urban gradient

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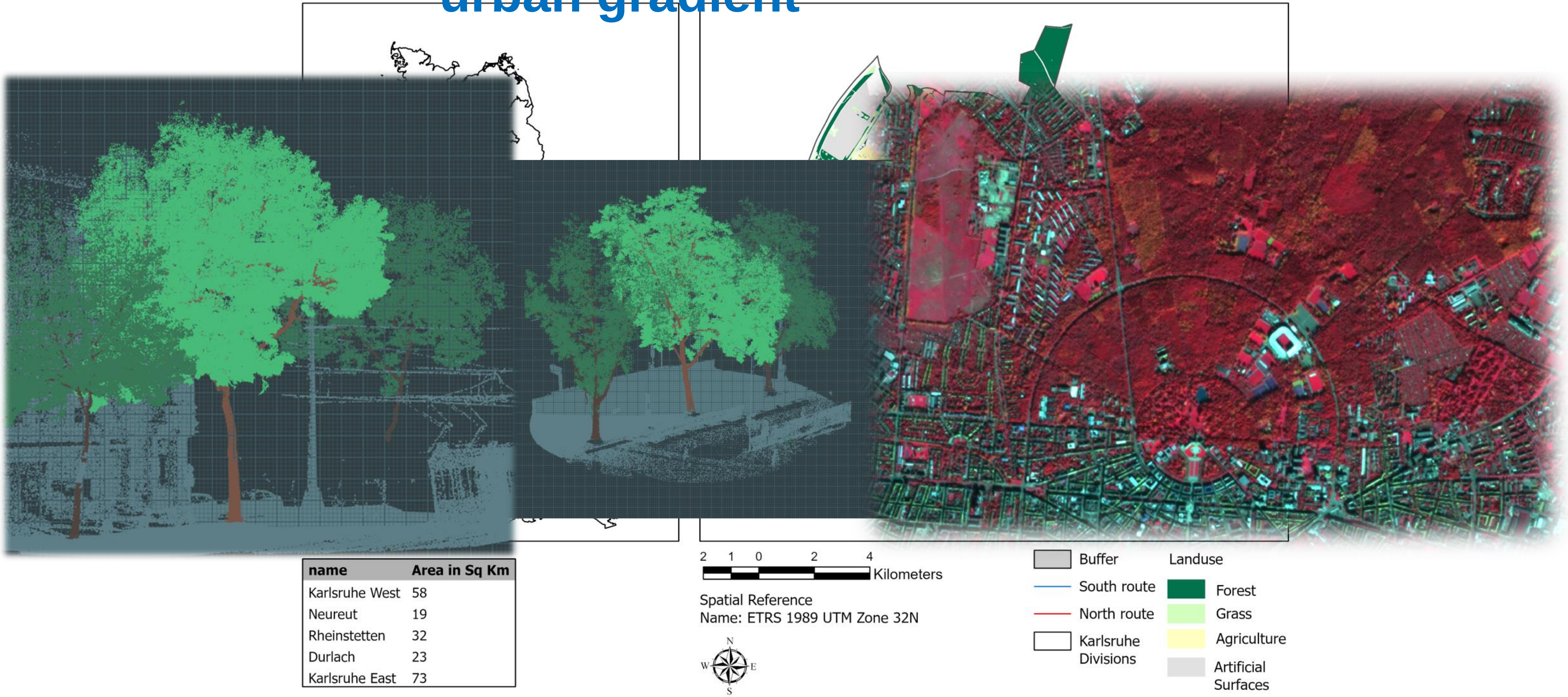


| name | Area in Sq Km |
|---|---|
| Karlsruhe West | 58 |
| Neureut | 19 |
| Rheinstetten | 32 |
| Durlach | 23 |
| Karlsruhe East | 73 |



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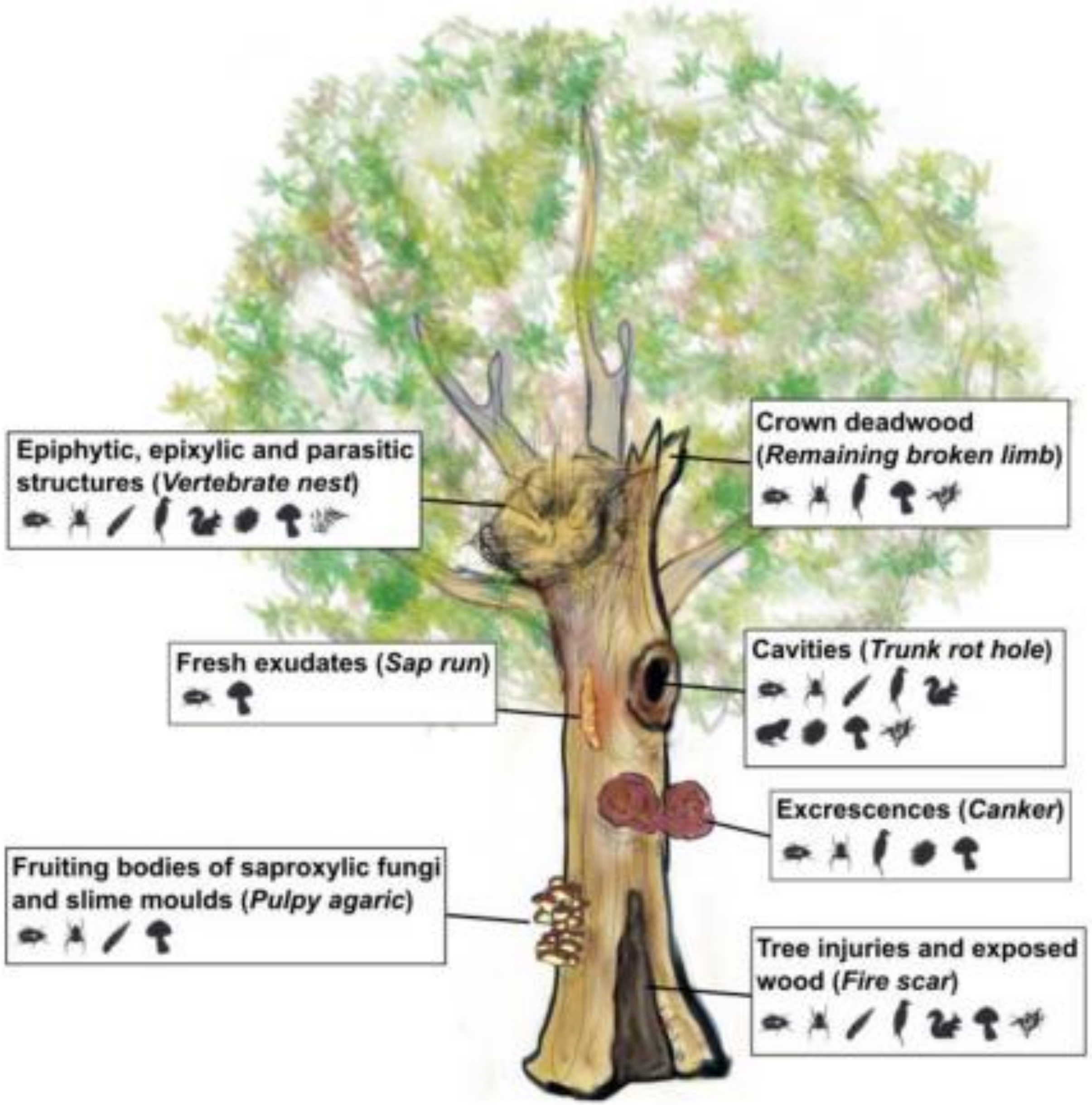
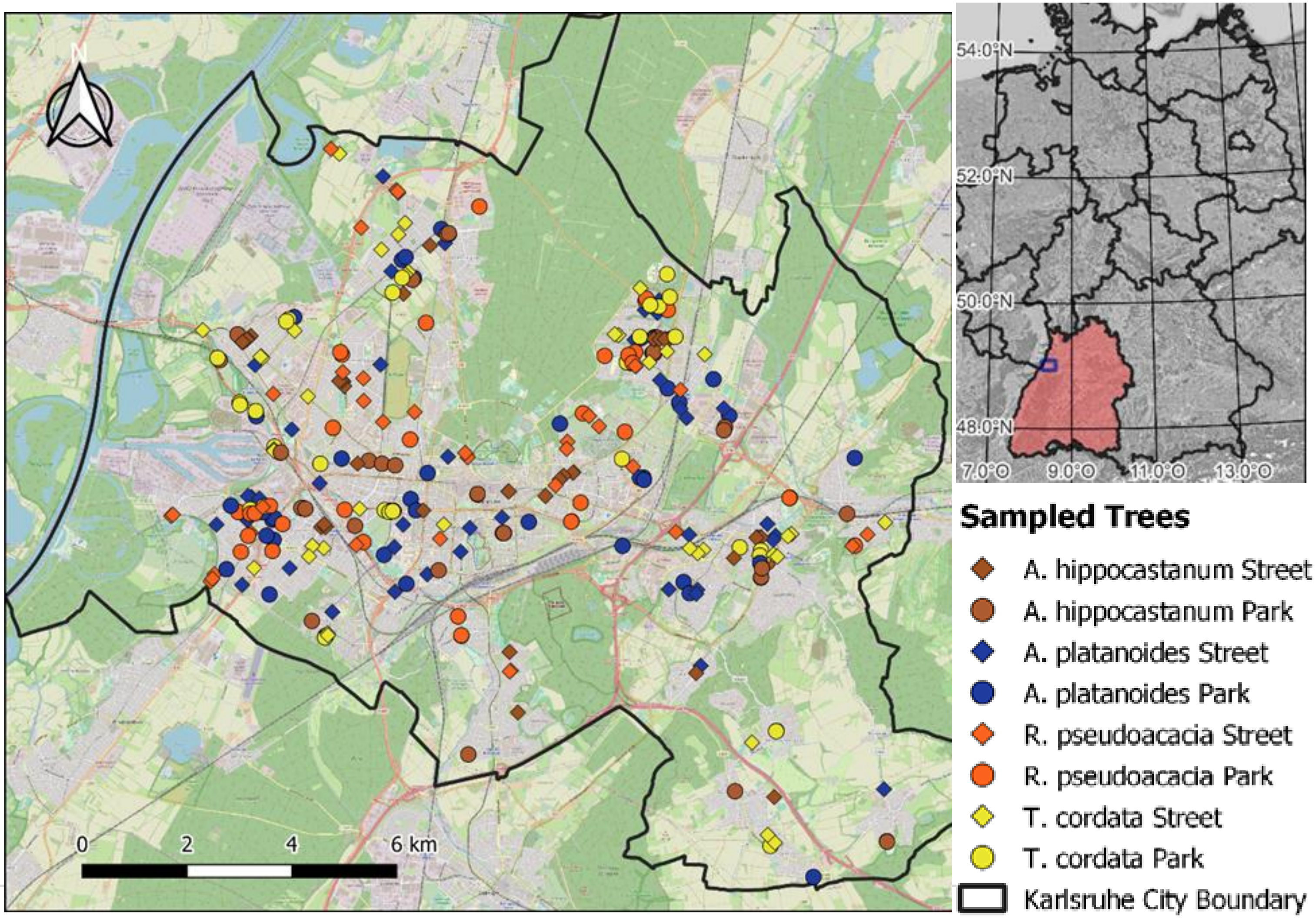
# Tree as a habitat: Mircohabitat

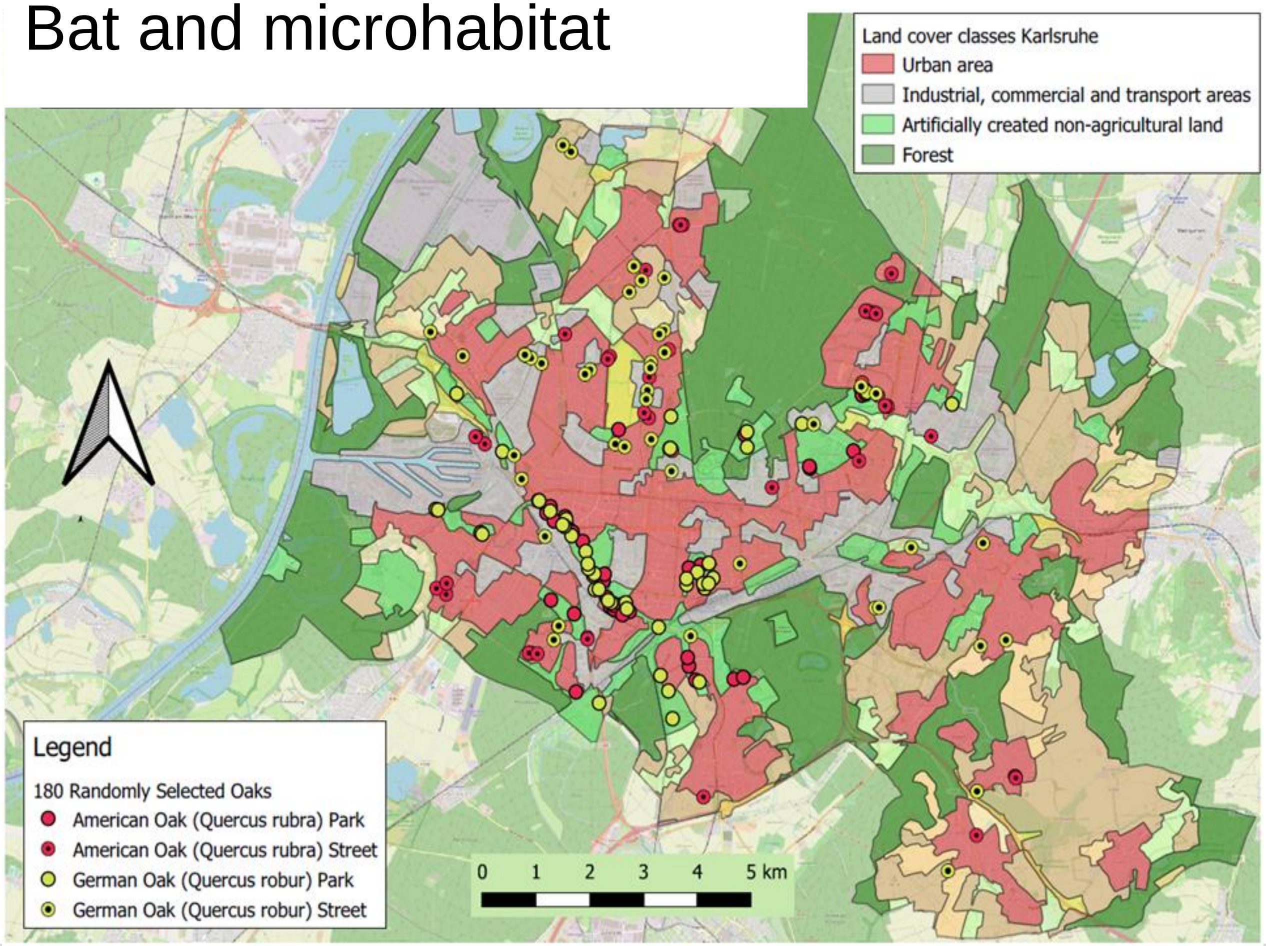


# Norway maple, horseshoe chestnut, Black locust and Linden: microhabitat



# Microhabitats and bats (☺) in parks and streets between Pedunculate oaks and red oaks

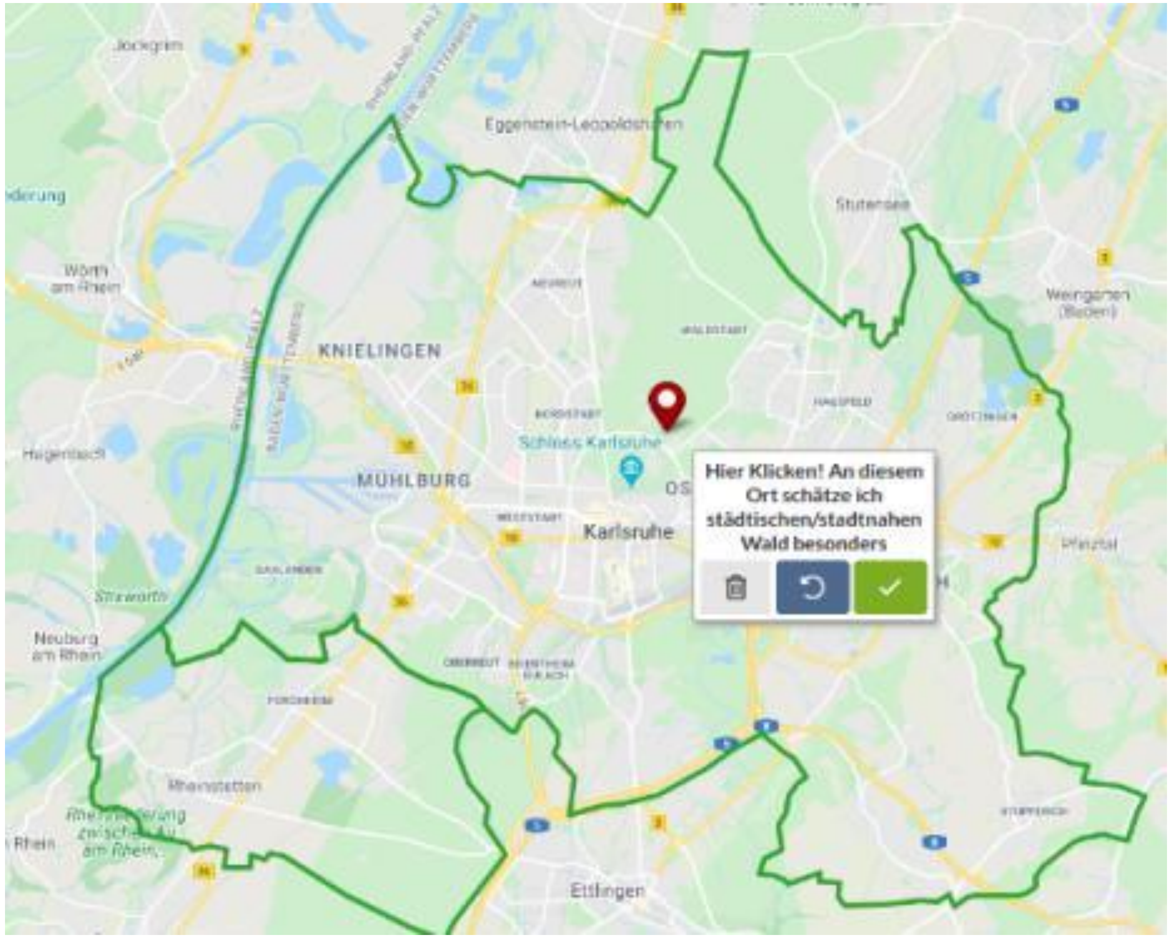
Bat and microhabitat

# Cultural ecosystem services (CES)

(1) How do the residents of Karlsruhe and Rheinstetten evaluate the cultural ecosystem services of urban forests?

(2) What impact has the COVID-19 pandemic had on these perceptions and the value citizens attribute to the urban forest?

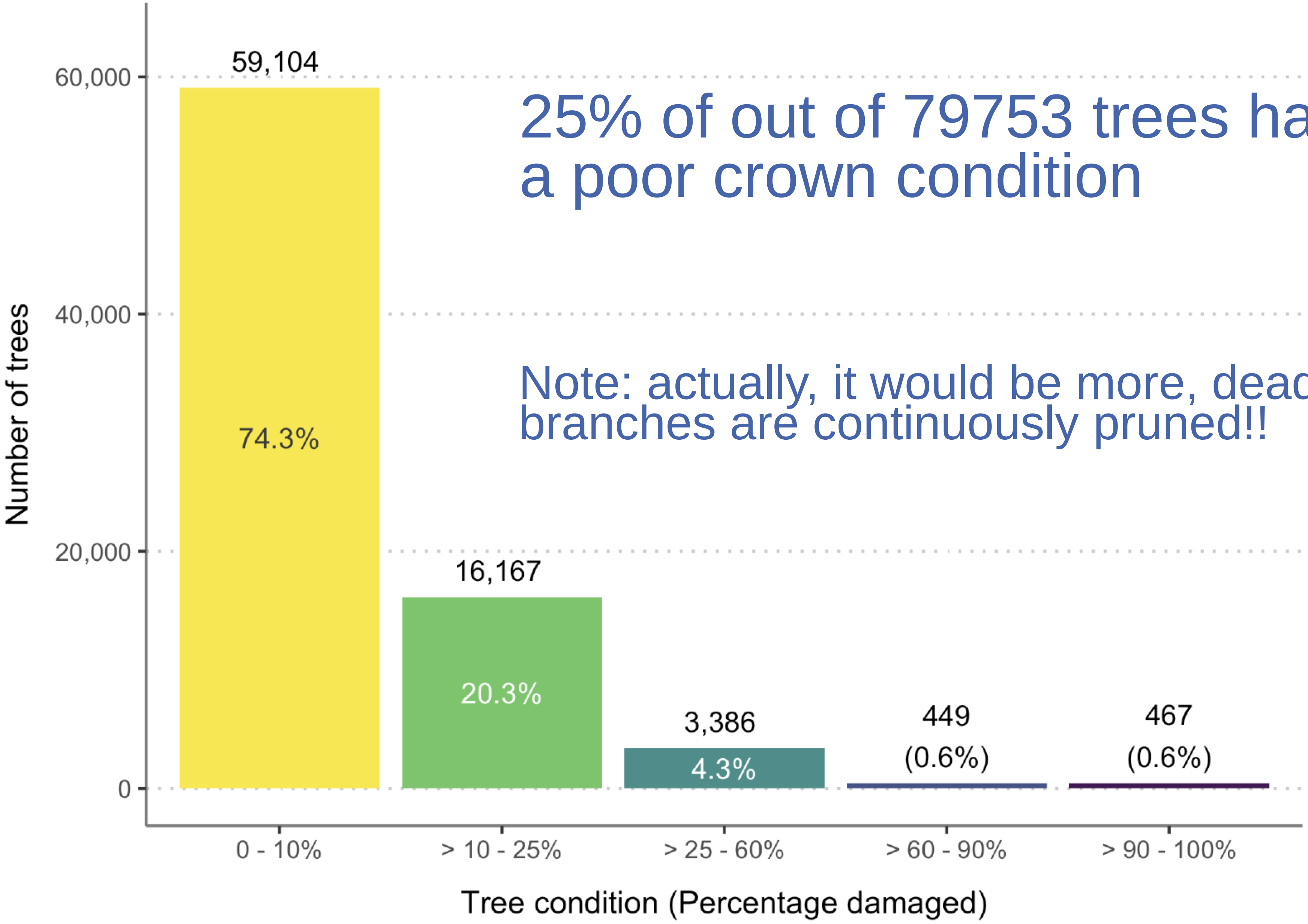



The survey was conducted in August and September 2020.

A total of 501 citizens from Karlsruhe and Rheinstetten took part in the survey.

# Results on tree health (current condition)

# Crown damage condition of solitary trees in Karlsruhe

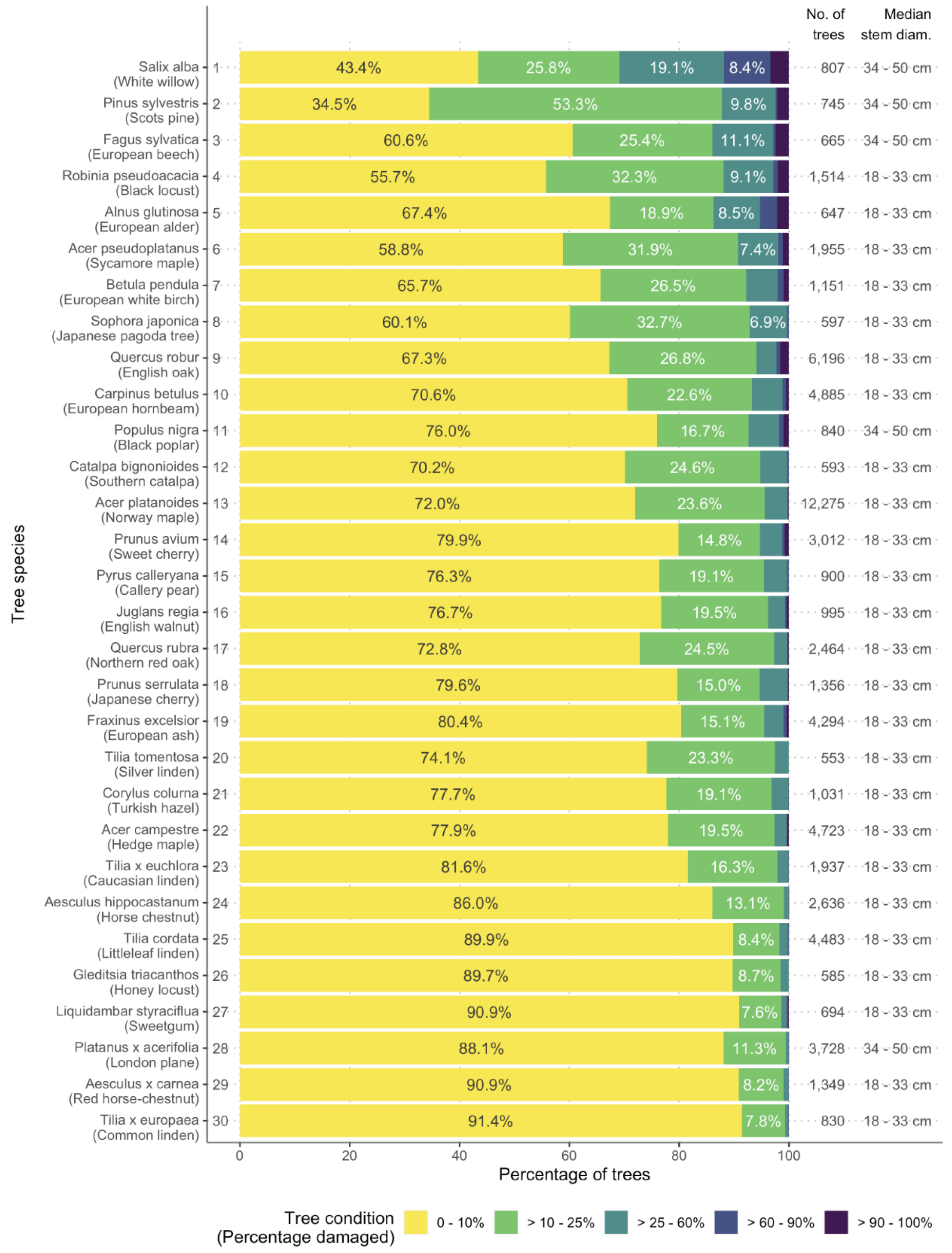



25% of out of 79753 trees have a poor crown condition

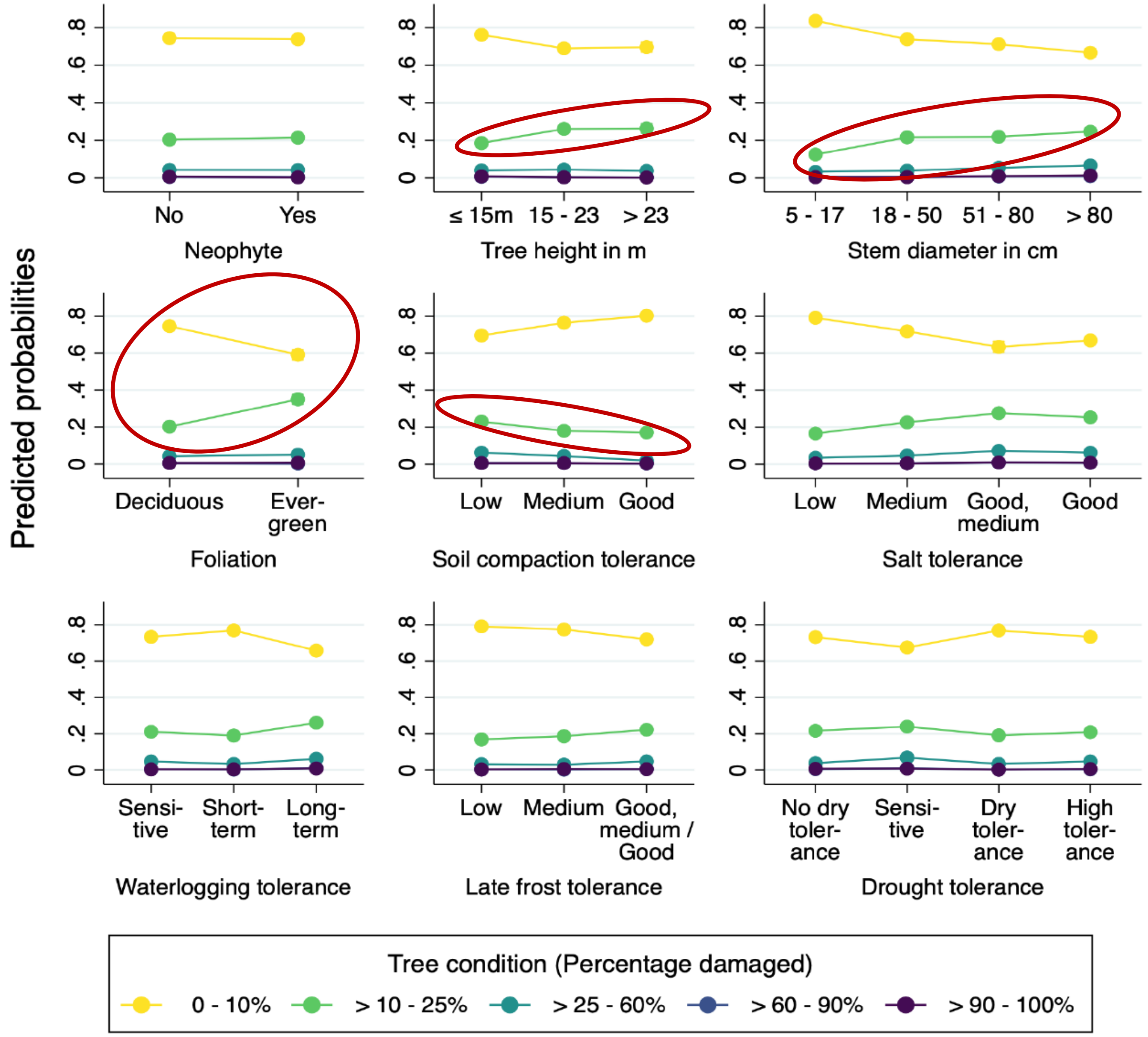
Note: actually, it would be more, dead branches are continuously pruned!!

# Crown damage in lonely city trees

- 30 species out of 111 species are presented here in these graphics
- High variation between species
- **Highest crown damage:** *Salix alba, Pinus sylvestris, Fagus sylvatica, Robinia pseudoacacia, Alnus glutinosa*
- **Lowest crown damage:** *Tilia x europaea, Aesculus x carnea, Platanus x acerifolia, Gleditsia triacanthos, Tilia cordata*

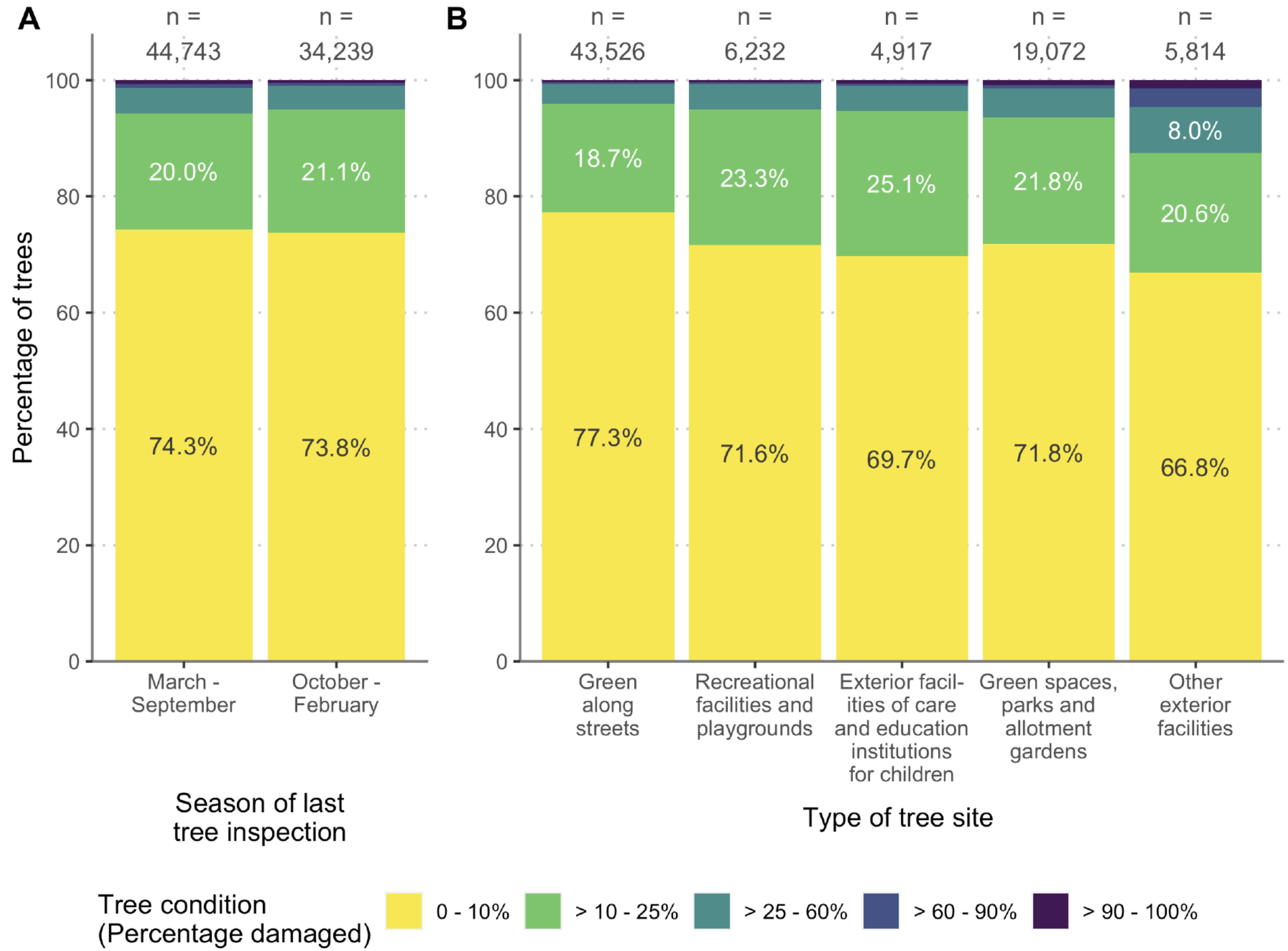


# Crown damage in single standing city trees




- Evergreen trees are more prone to crown damage
- Tolerance of roots to soil compaction reduces crown damage
- Moderate level of crown damage increases with tree size

# Tree inspection time and growing environment




- No difference in terms of the season of tree inspection
- Street trees have the lowest crown damage (pruning effect!)
- Trees in „other exterior facilities" have the highest crown damage

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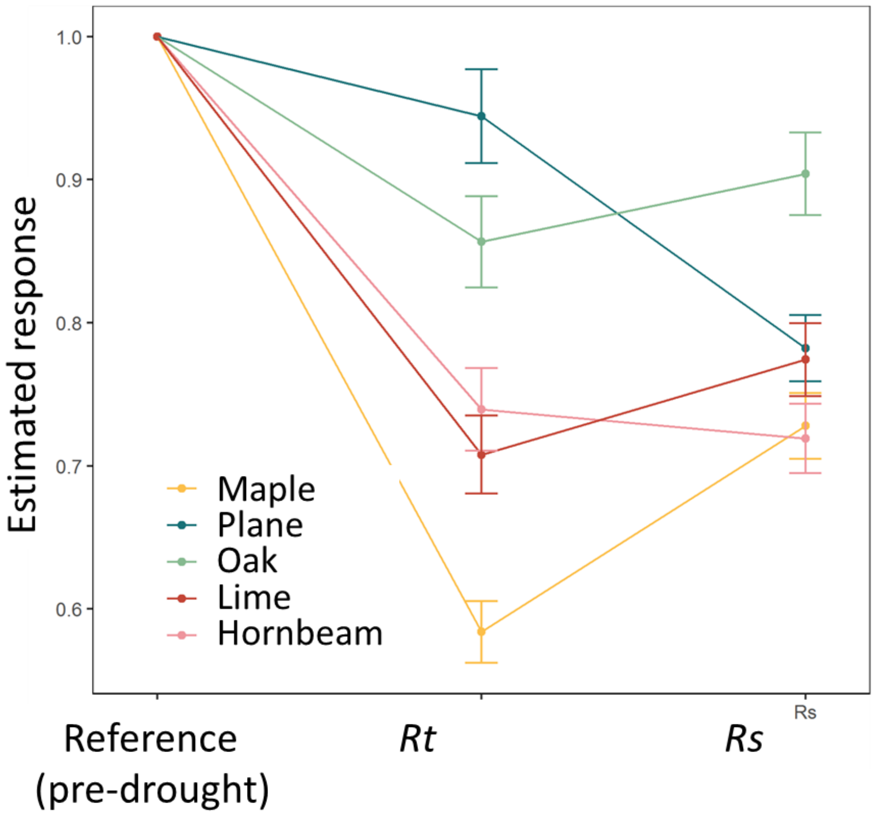
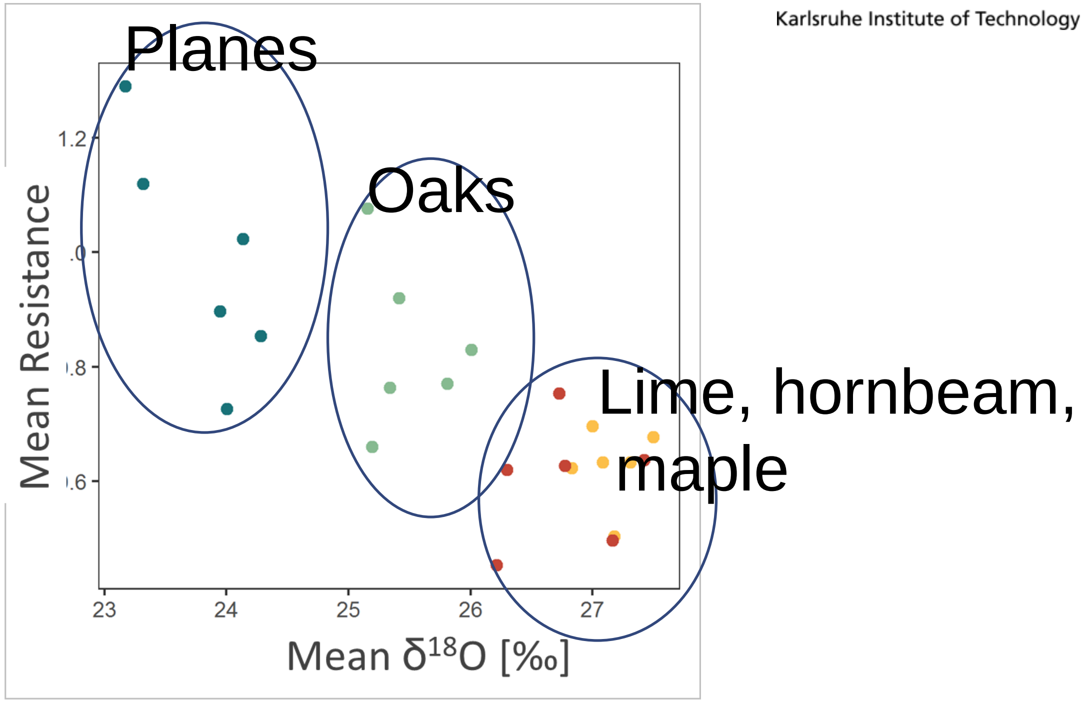
# Results on growth reaction to drought

# Growth response differs between species

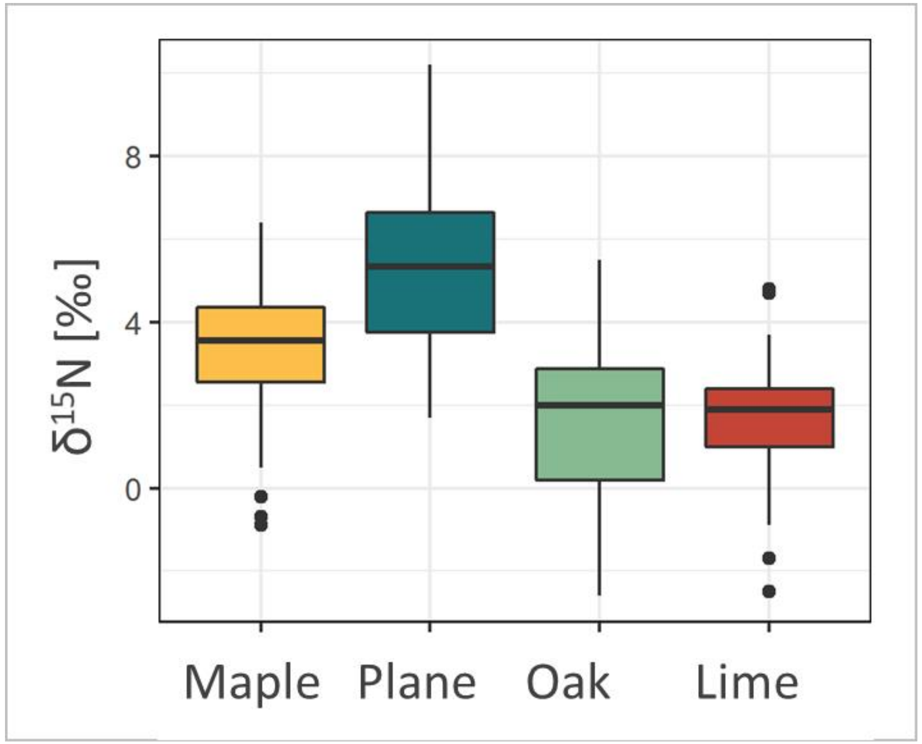


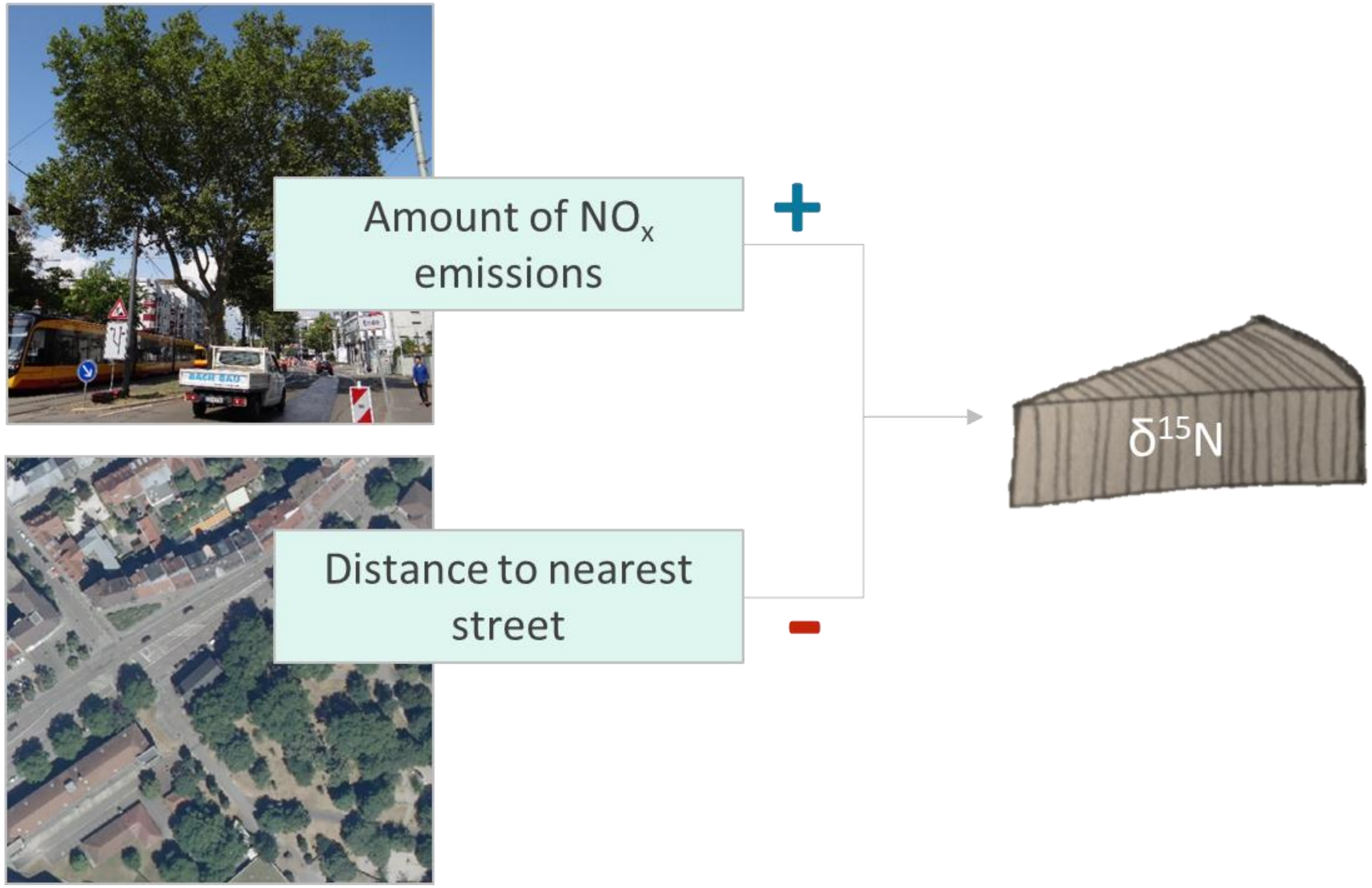



Plane trees have high resistance but low resilience. Native oaks have both high resistance and resilience. Delta O increases with lower resistance.

# N isotopes concentration varied between species and locations



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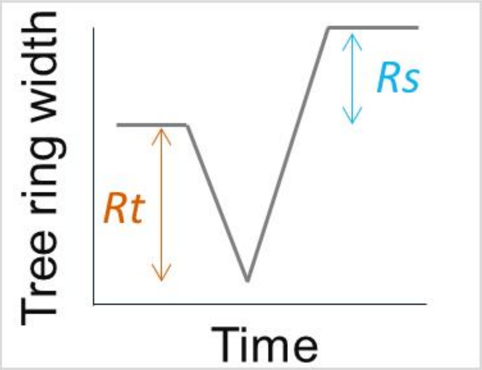
# Precipitation in spring is of high importance for tree growth

| Time period: 1982-2018 | | March | April | May | June | July | Sum JJA (prev. year) |
|---|---|---|---|---|---|---|---|
| Maple | $TRW_i$ | ↑ | | ↑ | | | |
| | $\delta^{13}C$ | | | ↓ | | | |
| | $\delta^{18}O$ | | | ↓ | | | |
| Oak | $TRW_i$ | ↑ | | ↑ | ↑ | | |
| | $\delta^{13}C$ | | | | | | |
| | $\delta^{18}O$ | | | ↓ | | | |
| Hornbeam | $TRW_i$ | | | ↑ | | | |
| Lime | $TRW_i$ | ↑ | | ↑ | | ↑ | |
| | $\delta^{13}C$ | | | ↓ | | | |
| | $\delta^{18}O$ | | | ↓ | | | |
| Plane | $TRW_i$ | | | | | | ↑ |
| | $\delta^{13}C$ | | | | | | |
| | $\delta^{18}O$ | | | ↓ | | | ↑ |

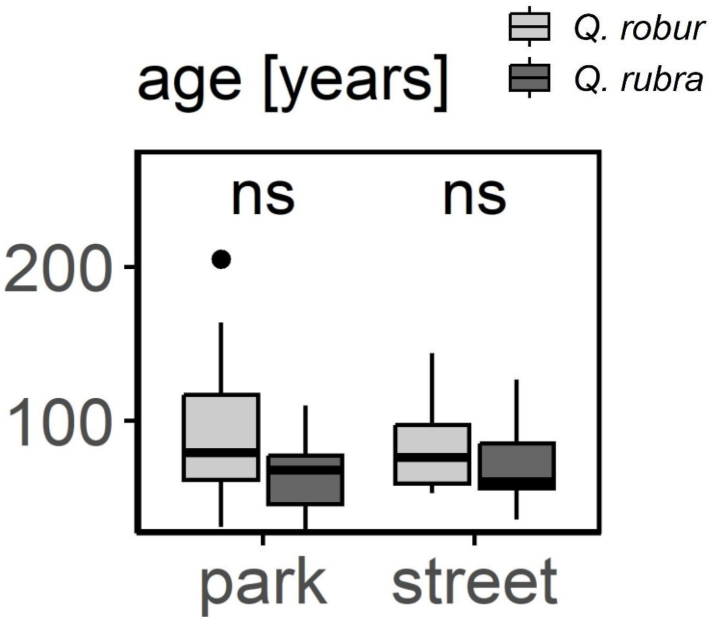
# Soil and tree characteristics were main drivers controlling growth, resistance and resilience

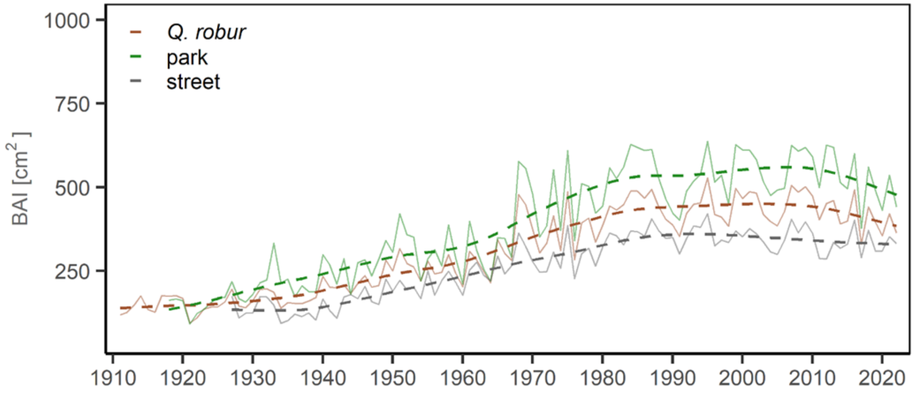
Resilience indices

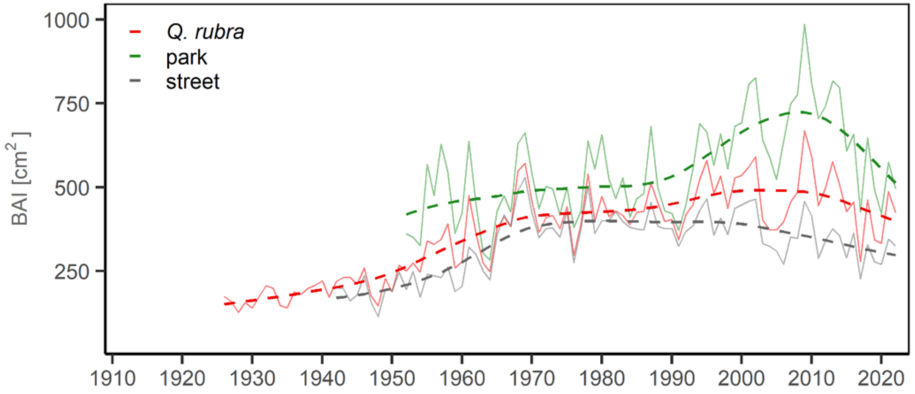



| | |
| --- | --- |
| ✗ | Distance to street |
| ✗ | Traffic emissions |
| (✓) | Soil properties |
| ✓ | Tree properties |

# Native vs. exotic red oak growth in park and street



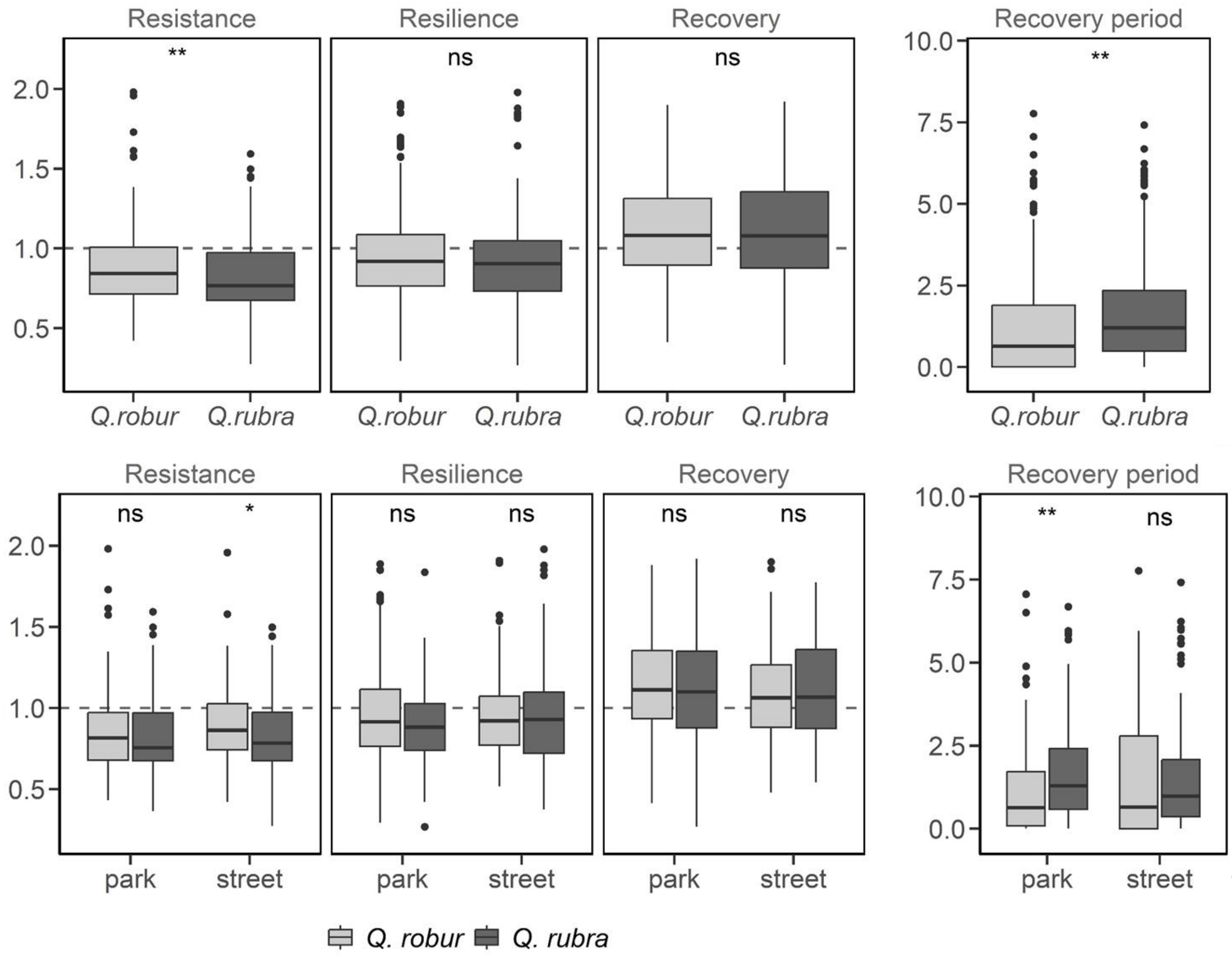




- *Q. robur* in parks were older than Q. rubra

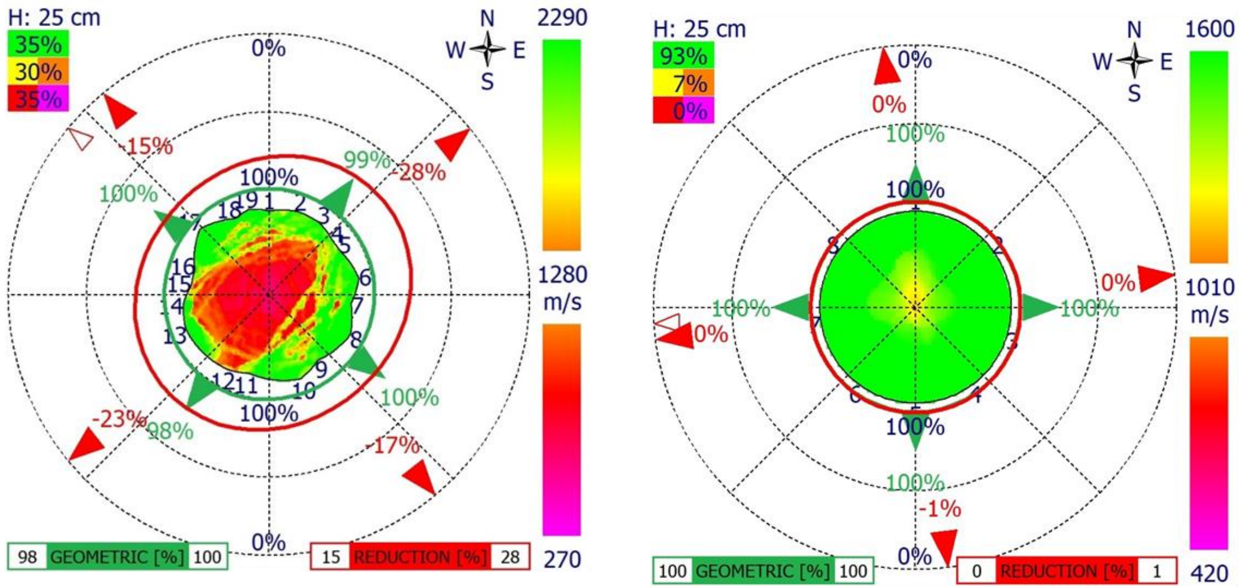
- In the first 50 years, *Q. rubra* grew better than *Q. robur*
- Higher growth in parks than in streets

# Growth reaction to drought in pedunculate and red oak in streets and parks

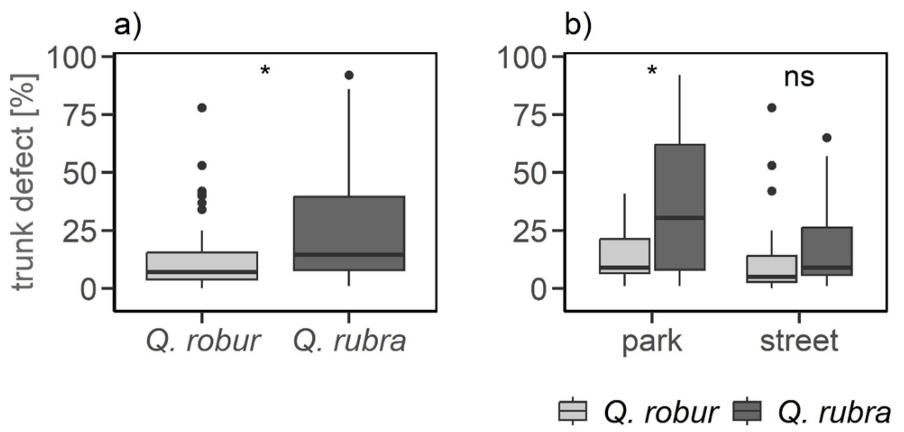



- *Q. robur* has a higher resistance to drought (except in 2018!) than *Q. rubra*
- Recovery from drought needs more time in *Q.rubra* than in *Q.robur* since 2003

# Trunk damage in pedunculate oaks and red oaks



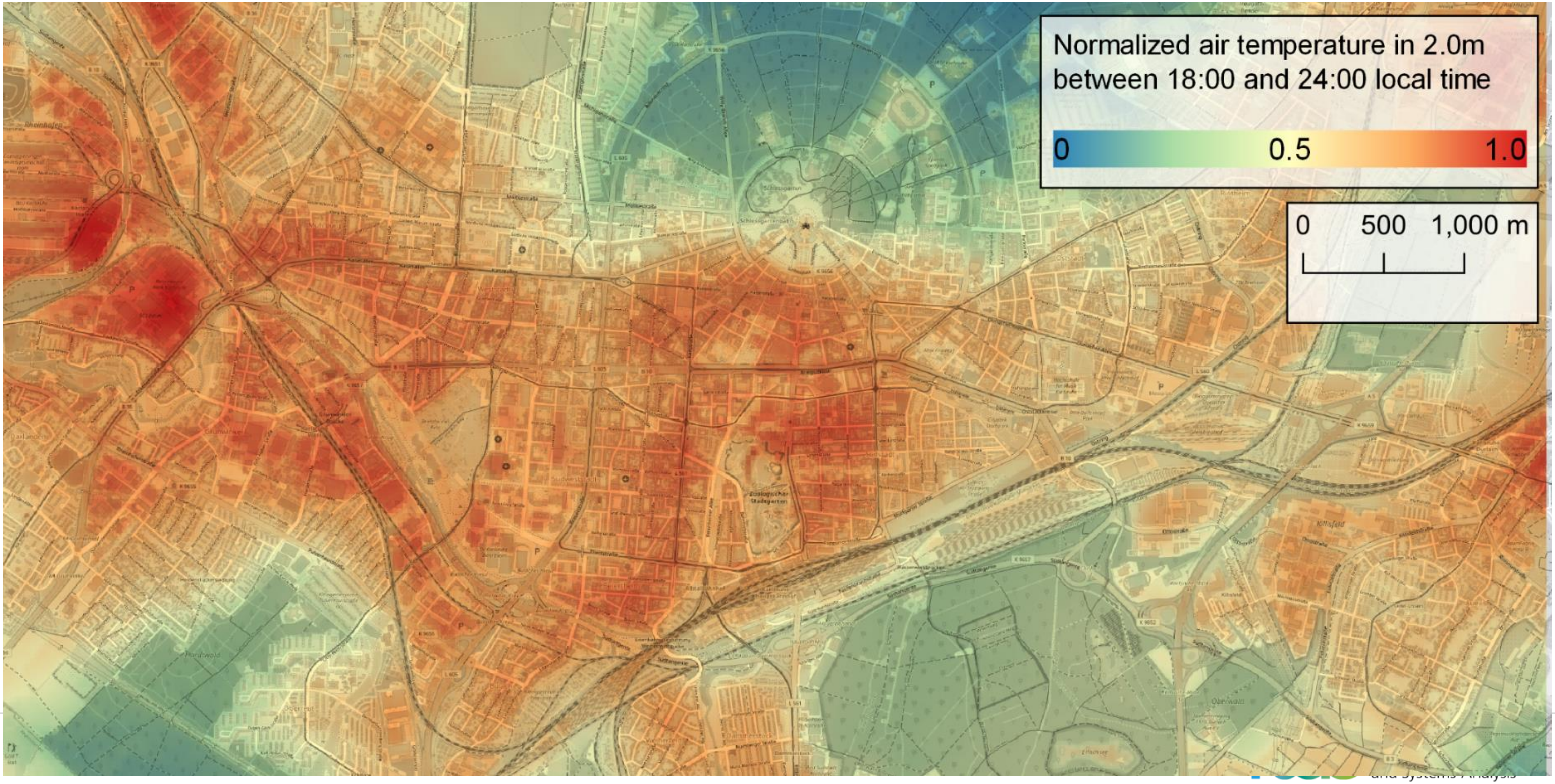

Sonic tomograph of a health (right) trunk without decay (right) and unhealthy stem (left) with decay



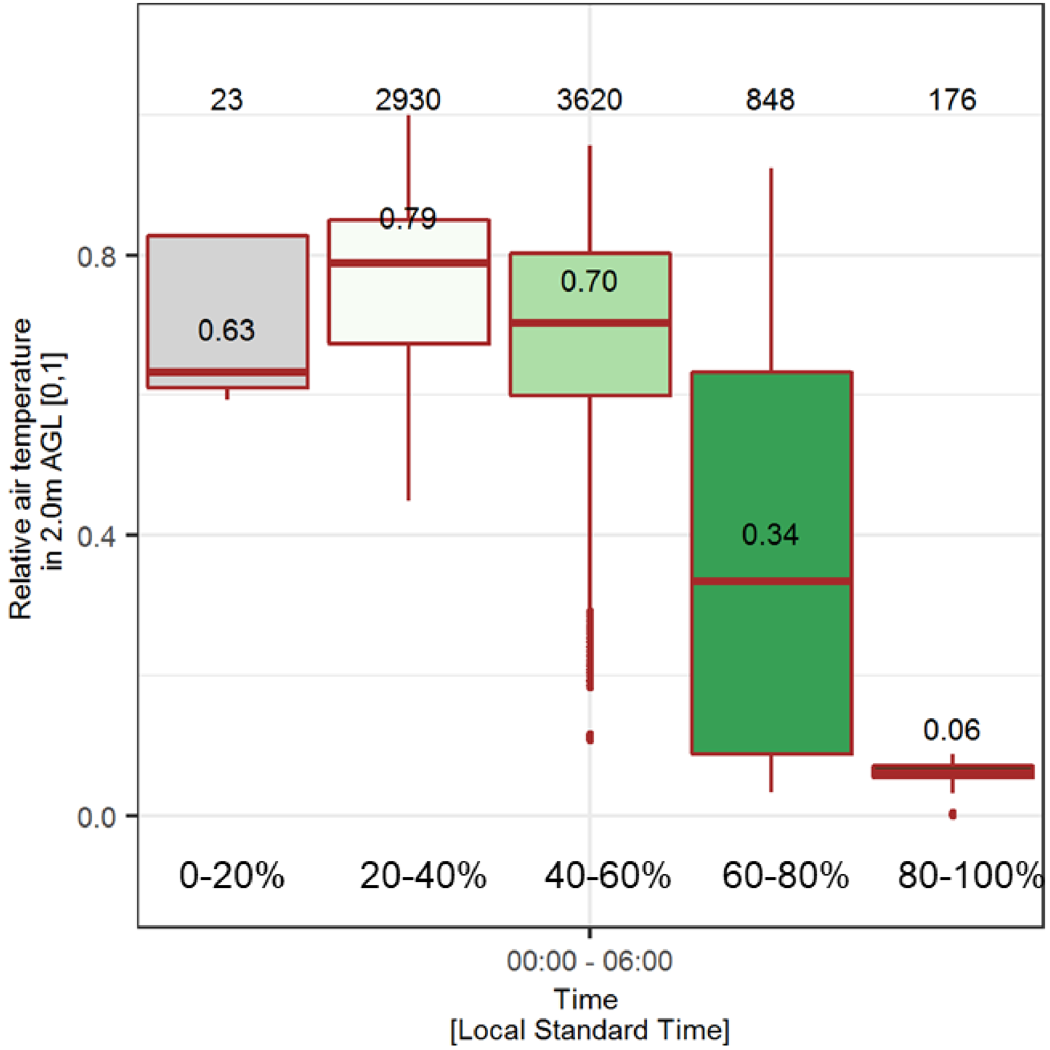

- *Q. rubra* had more internal trunk defects than *Q. robur*
- Internal trunk defects were higher in park *Q. rubra* trees than *Q. robur* trees

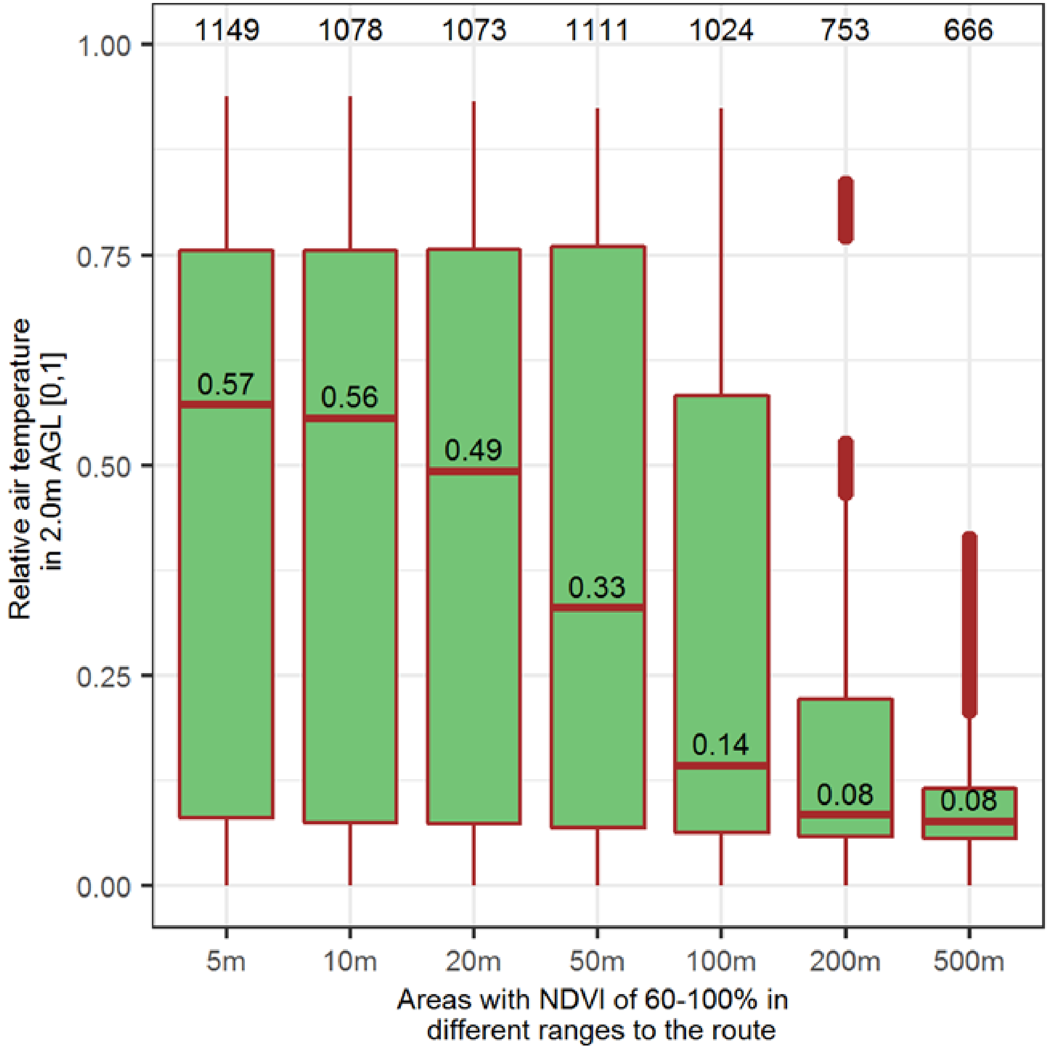
# Results on trees‘ influence to heat mitigation

# Thermal exposure: detection of hotspots

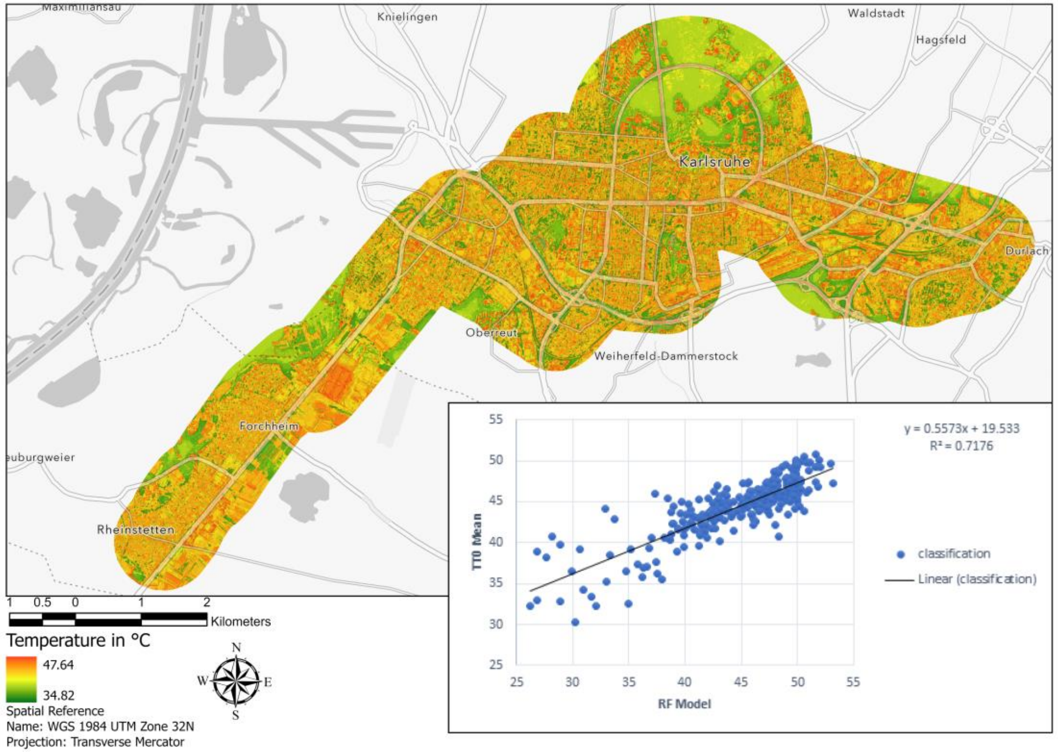


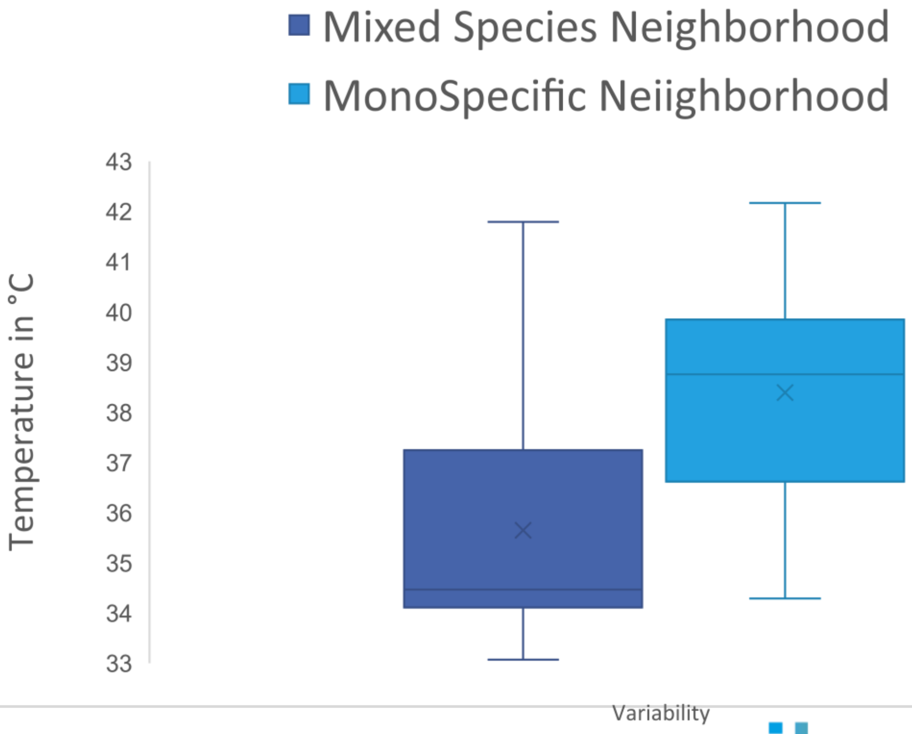
# Spatial neighborhood analysis – NDVI and relative air temperature (0.00 to 06.00 UTC)



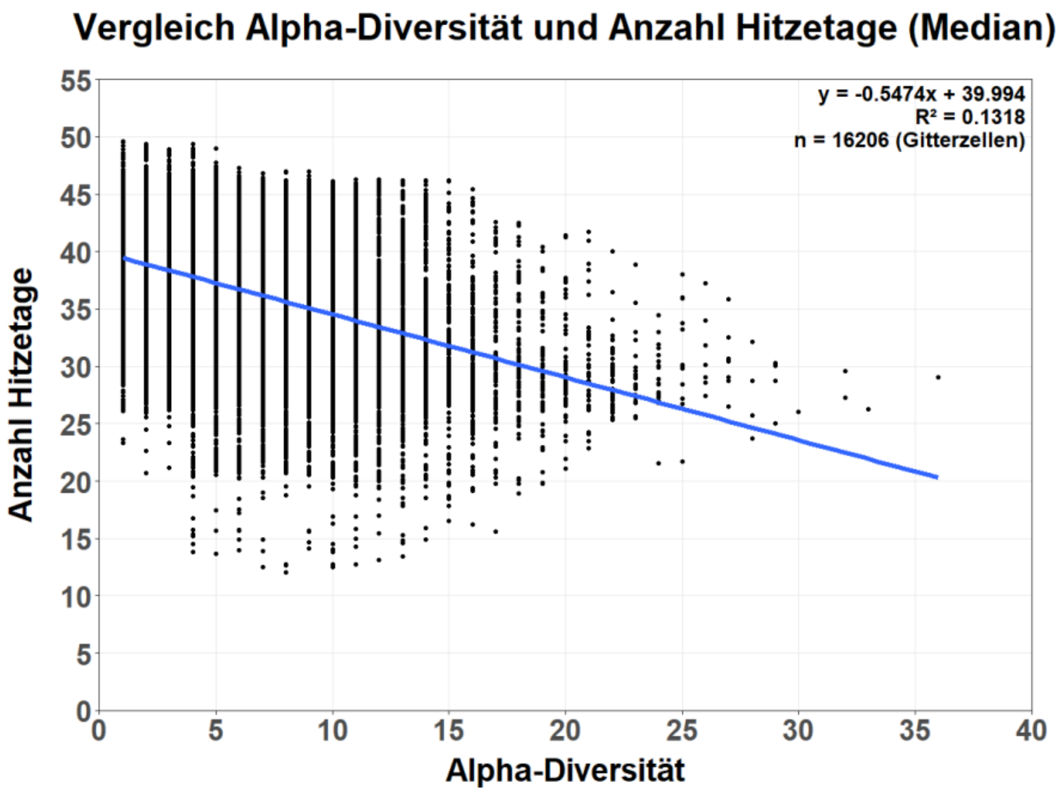



# Streets with mixed species were cooler zhan monospecific streets with the same leaf area after cancelling out water evaporation and building shading effect! Need to find the causality – further research will be done

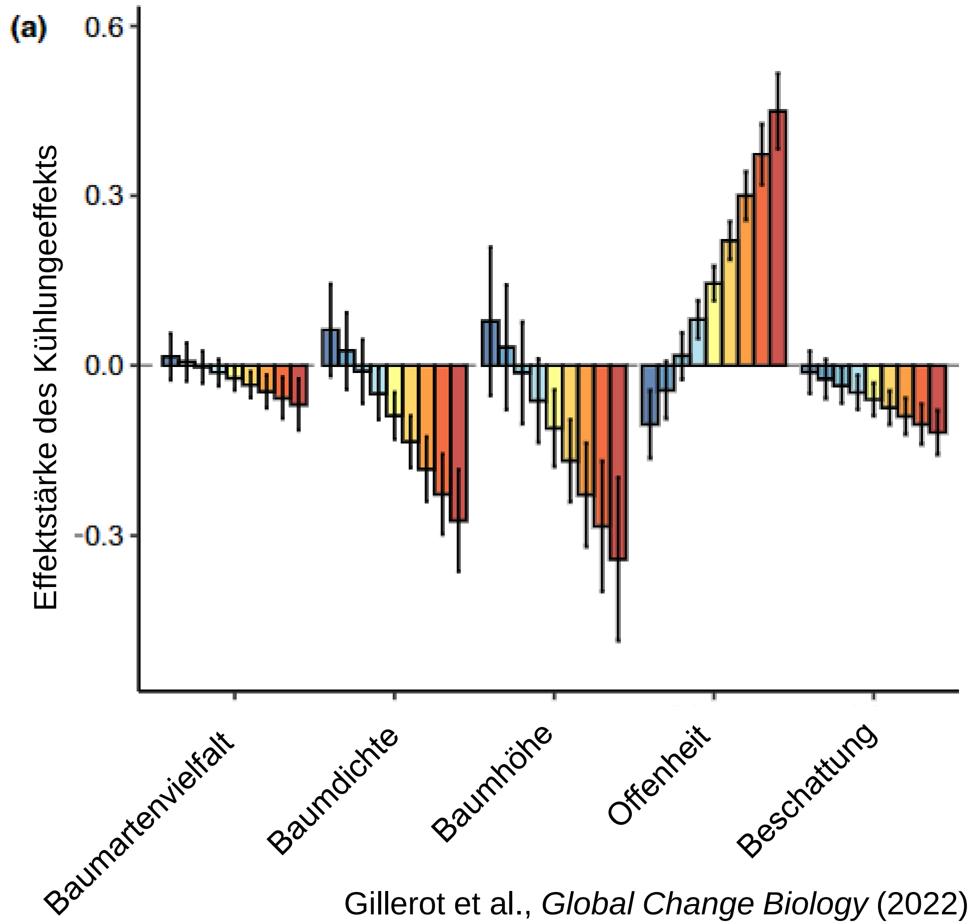


# MEHR BIODIVERSITÄT GLEICH WENIGER HITZE?




Schütz, *Projekt GrüneLunge* (2021)




Gillerot et al., *Global Change Biology* (2022)

# Results on microhabitat

(Martin et al 2022)

# Microhabitat richness on *Quercus robur* and *Quercus rubra* between parks and streets

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- Exotic red oaks had fewer crown dieback than native pedunculate oaks
- BUT, healthy oak trees had fewer tree microhabitats than unhealthy oaks

# Bat activities near native and exotic oak trees at street and park

***Pipistrellus* bats:**
prefer parks but not differentiate species

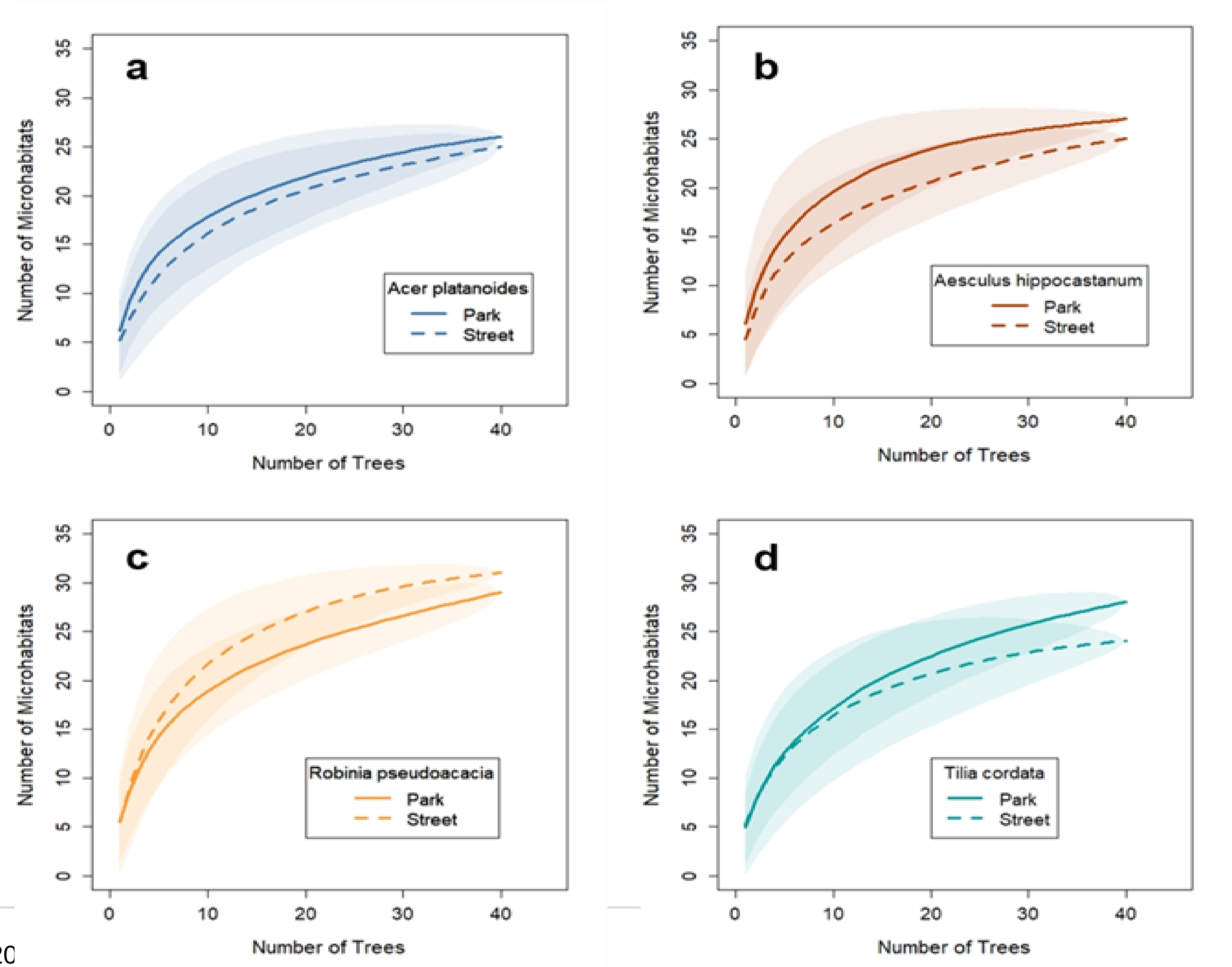
**Brown long-eared bats (*Plecotus*):**
prefer native oaks
prefer parks
prefer trees with fork split, sunscald damage and woodpecker holes

**Noctule bats (Nyctalus):**
neither differentiate between trees nor between habitats

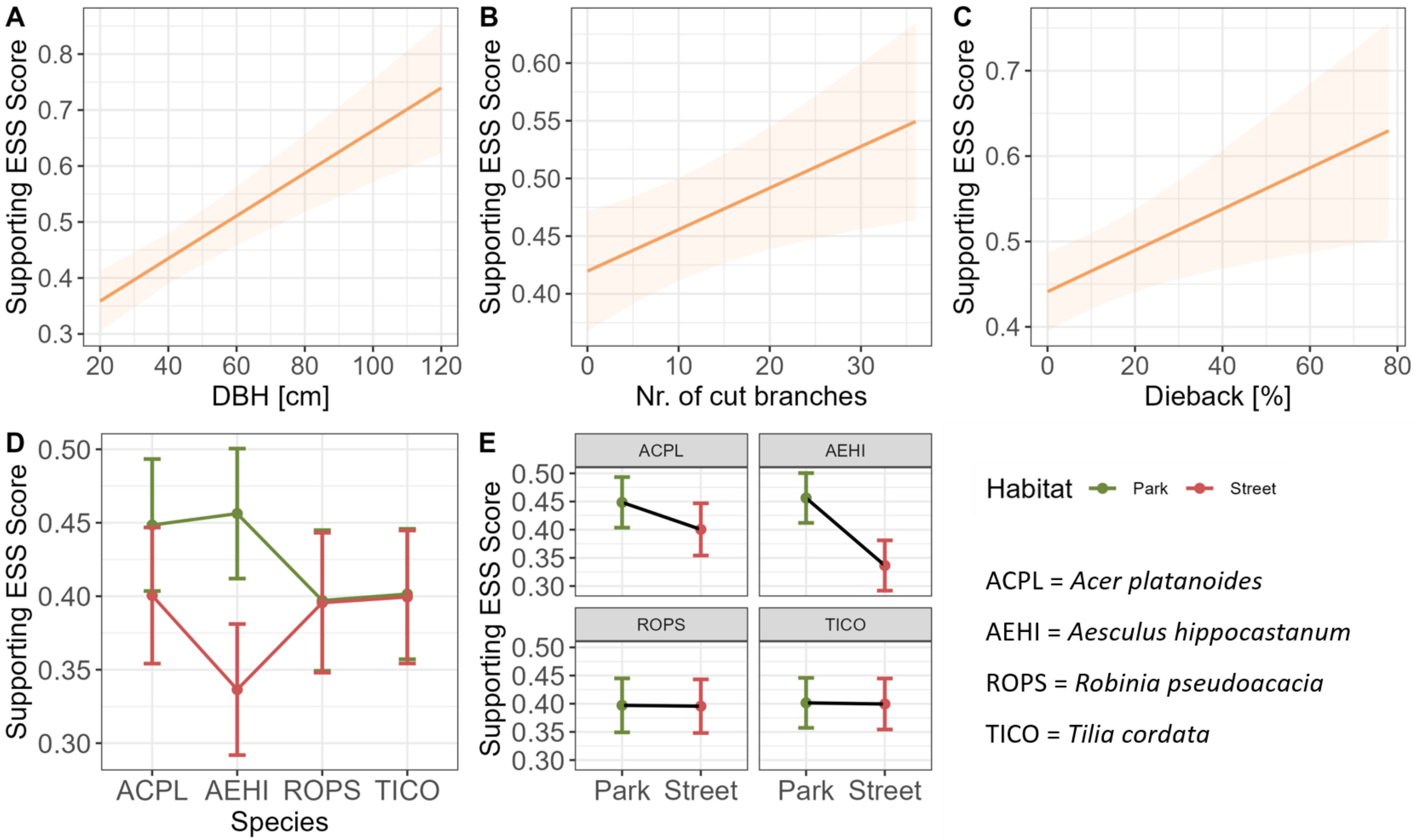


Image sources: Pixabay and Google

# Microhabitat richness on other common species between parks and streets



# Factors which influenced tree microhabitat




ACPL = *Acer platanoides*

AEHI = *Aesculus hippocastanum*

ROPS = *Robinia pseudoacacia*

TICO = *Tilia cordata*

# Trade-offs between ecosystem services

# Ecosystem services assessed from 2968 trees (201 plots)

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| Provisioning ecosystem services | Unit |
|---|---|
| Leaf biomass | kg/ha |
| $CO_2$ storage | kg/year |
| Non-timber forest products<br>• Edibility<br>• Medicinal uses<br>• Decorative uses<br>• Other uses | Number |

| Supporting ecosystem services | Unit |
|---|---|
| Microhabitat abundance | Number |
| Microhabitat richness | Anzahl |
| Tree species diversity | Shannon index |
| Tree size diversity | Gini index |

| Regulierende ÖSL | Einheit |
|---|---|
| Oxygen production | kg/year |
| $CO_2$ sequestration | kg/year |
| Hydrological benefits<br>• Potencial evapotranspiration<br>• Evapotranspiration<br>• Transpiration<br>• Water intererception<br>• Avoiding surface runoff | m3/year |
| VOCs Emissions<br>• Isoprene<br>• Monoterpene | g/year |
| Pollution removal<br>• Ozone ($O_3$)<br>• Nitrogen di-oxide ($NO_2$)<br>• Sulphur dioxide ($SO_2$)<br>• PM2.5 | g/year |

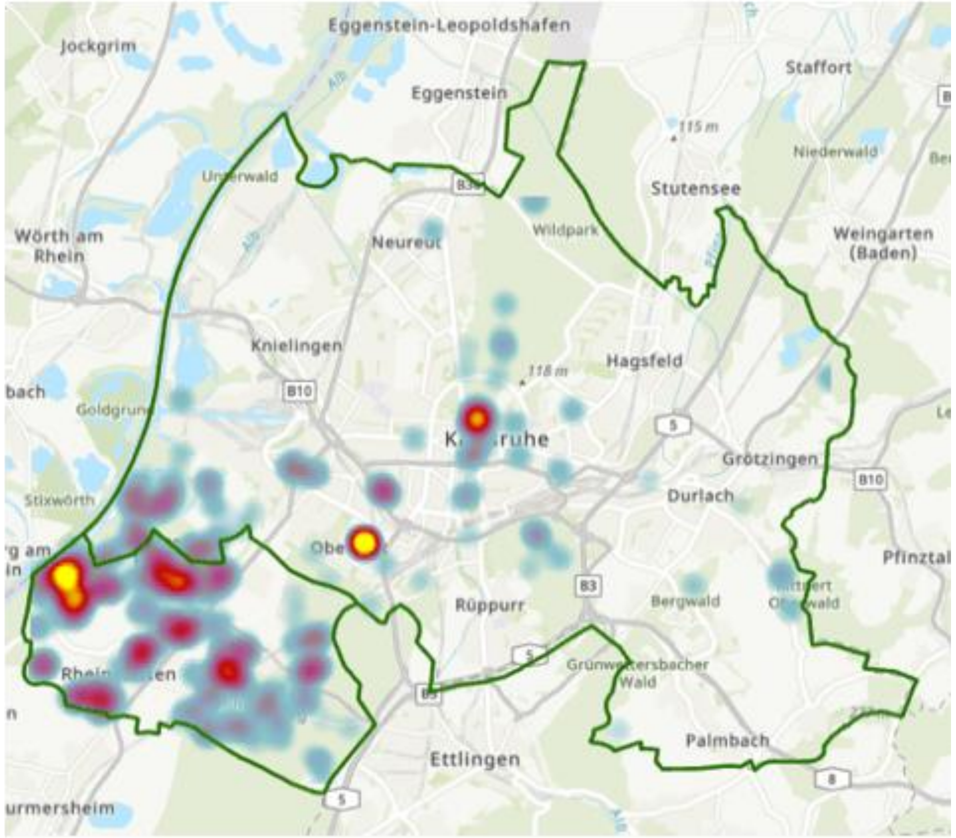
# Trade-offs and synergies between ecosystem services

- Trade-offs were first statistically calculated at plot level and then spatially upscaled
- Supporting ecosystem services have trade-offs with regulating ecosystem services
- However, regulating ecosystem services have synergies with provisioning ecosystem services

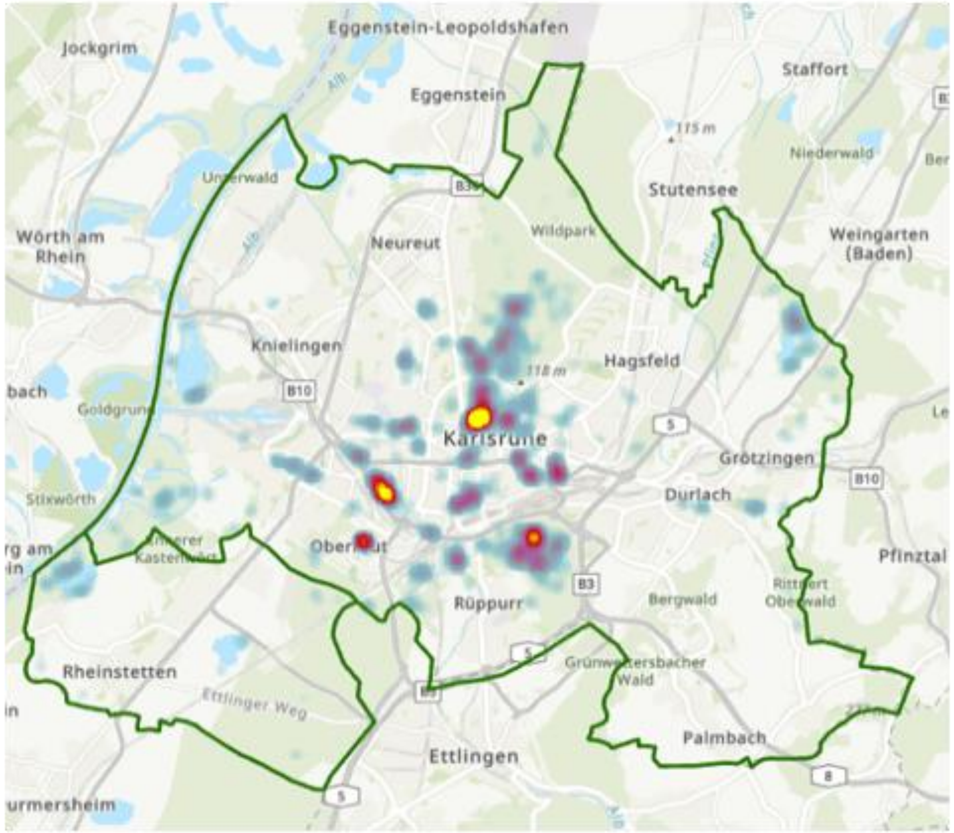
# Results on cultural ecosystem services from tree

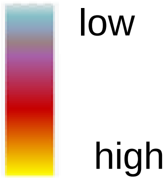
# Comparison of CES evaluation

## Residents of Rheinstetten
(n=97; 316 evaluated points)




## Residents of Karlsruhe
(n=402; 1253 evaluated)




Density of selected sites (weighted by the sum of the perception of all values of CES)

# Influence of Covid-19 pandemic

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**> 90%**

… of respondents indicated that the urban and peri-urban forest was particularly important to his/her well-being during the COVID-19 pandemic.

**70%**

… of respondents visit the urban and peri-urban forest more often during the COVID-19 pandemic than before.

@istock



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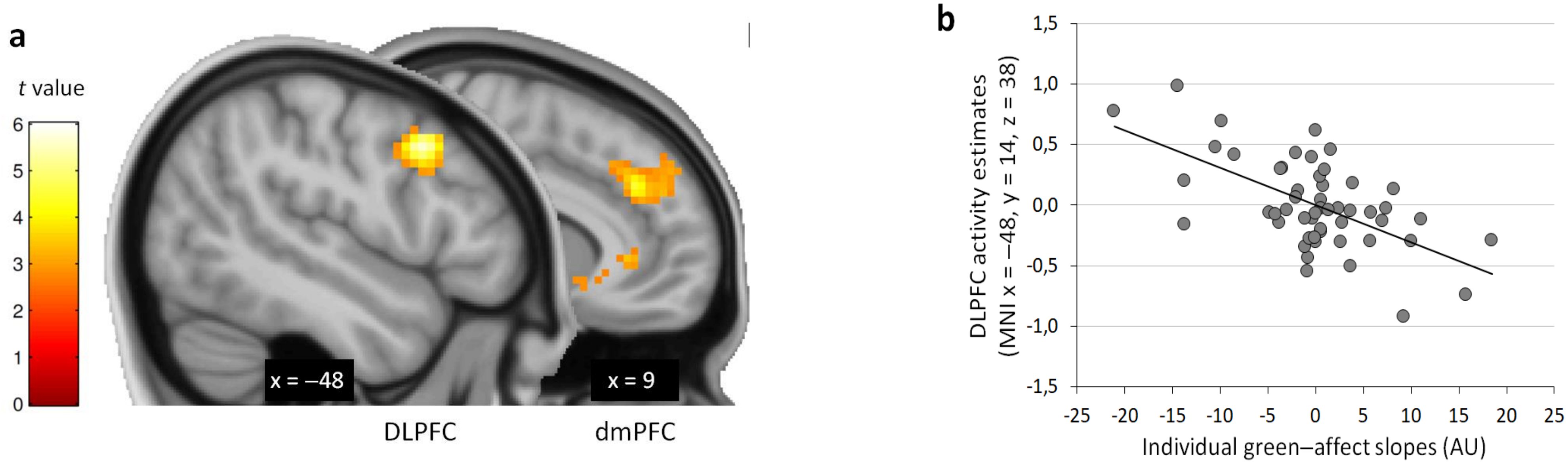
# Why trees help human mental health?
# Neuronale Korrelate des Grün-Effekts

Karlsruhe Institute of Technology




**Grünerleben im Stadt-Alltag kann reduzierte präfrontale Kapazität kompensieren.**

Tost*, Reichert*, Braun* et al., *Nature Neuroscience* 2019

# Creation of transdisciplinary, deliberative democratic formats in urban forest management

- We created multiple formats of stakeholder engagements involving researchers, city administrations, citizens and other stakeholder (we created a forum called „Stadtbaumforum“)
- We used our university‘s „Real World Lab“ (*Reallabor* in German) for this purpose
- We developed guidelines for close to nature urban gardening with citizens and we found high interest among citizens to get engage with researchers and city administrations for improving the management of their private gardens

# Main conclusions

- High trade-offs exist between supporting and regulating ecosystem services
- Poor tree health conditions prevailed in the study area
- Spring drought reduced growth (we are creating climate smart sensor-based irrigation in Karlsruhe)
- Drought response varied between species but native European Oaks and exotic Plane trees performed well to drought
- Exotic red oak may be better in streets if target is to keep them for 50 to 60 years, native oaks should be planted more in parks
- Tree cover and reduce night temperature during heatwaves
- Species diversity reduce air temperature
- High support for the cultural ecosystem services were found

# Tips for urban plant nurseries ☺

- Diversify the flora
- Increase phenotypic diversity in nursery production (lots of research need to be done)
- Propagate more trees with higher tolerance to xylem cavitation and drought
- GrüneLunge project will create a portal for future tree species selection (to be published by December 2023)
- Increase fine-root biomass
- Need more research and networking between nurseries, GBAs, and universities in Germany

# Papers from GrüneLunge project

Karlsruhe Institute of Technology

- https://www.nature.com/articles/s42949-023-00096-y
- https://www.sciencedirect.com/science/article/pii/S2212095523002183
- https://www.sciencedirect.com/science/article/pii/S1618866723001061?via%3Dihub
- https://www.sciencedirect.com/science/article/abs/pii/S0048969722057023
- https://link.springer.com/article/10.1007/s00468-022-02294-0
- https://www.sciencedirect.com/science/article/abs/pii/S2210670722002256
- https://publikationen.bibliothek.kit.edu/1000149438
- https://publikationen.bibliothek.kit.edu/1000123731

# More diversity

Simple, low species park

Complex, high species park

**Thank you**



Graphic creators: Arturo Romero Carnicero, Caroline Thomas ☺

# Synthesis

Involving city as an active project partner helped us to develop transdisciplinary formats. Urban forests are critical infrastructure and improvement of it will increase social resilience of the city

A sustainable supply of ecosystem services and low trade-offs can enhance sustainability. Sustainability may enhance ecological resilience

Perceptions by stakeholders and citizens on the importance of the cultural ecosystem services from urban forests may change over space and time. However, we should continuously monitor these perceptions. This will help us to create an inclusive and just city and increase social resilience

**Social-ecological resilience**

Studying the health of trees based on morphological symptoms during droughts can provide a general picture of resistance and recovery of different tree species in UPFs. A healthy tree population should increase ecological resilience

Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg

The potential of urban forest cover in thermal stress reduction among citizens should be a key component to consider in the creation of future urban forests. This will contribute in social resilience

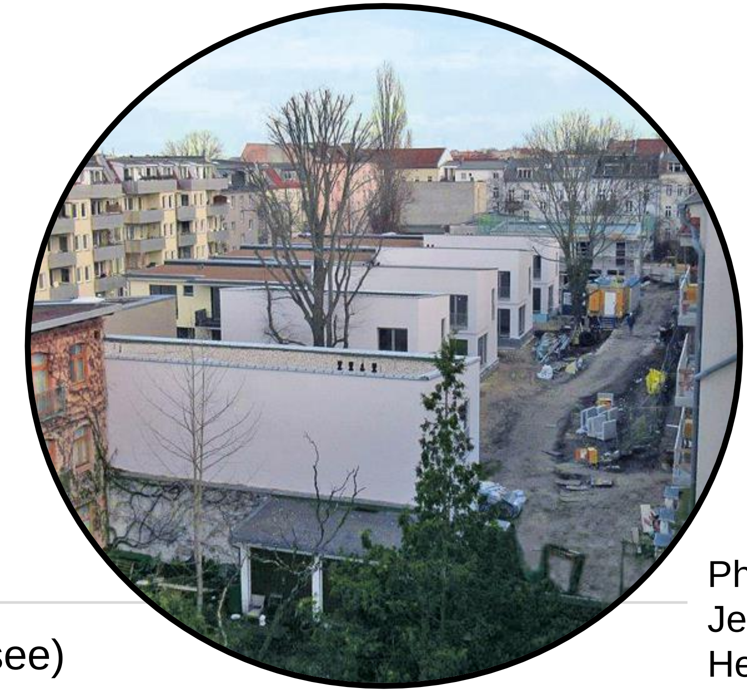
A retrospective dendroecological and stable isotope study on tree rings of urban species can help us to understand how resilient trees were to past events of drought and improve our understanding of ecological resilience at species level

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

and Systems Analysis


Street trees
in Bochum City **May (!) 2018**

Street trees in Berlin **May (!) 2018**



Densification
(example Berlin-Weißensee)

Photos:
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Helmholtz GFZ Potsdam